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THE NEW SEWAGE PURIFICATION WORKS FOR BERLIN-WILMERSDORF, GERMANY.

By WM. PAUL GERHARD,* C. E.

One of the largest and most recent biological sewage purification plants is the one located at Stahnsdorf, near Berlin, Germany, completed in the year 1906. The writer visited this plant during a very cold spell in February, 1907, and subsequently secured through a photographer some views, especially taken for him, which are reproduced in the illustrations accompanying this article.

It is well known that a large part of the sewage of Berlin has been purified for years by broad surface irrigation. The German metropolis has grown very rapidly in the last decade, and a suburb like Wilmersdorf, which years ago was a villa district, but sparsely built up, has changed and now shows in its streets and buildings a thoroughly urban character, and is really a part of Greater Berlin, though under a separate municipal government. Accordingly, when it became necessary to enlarge its sewerage facilities, it was decided by the authorities to retain in the built-up sections the combined system, and to introduce the separate system of sewerage for parts which were less thickly settled; 205 ha. (hectares) (or 506.6 acres) of the district are sewered on the combined, and 615 ha. (or 1,520 acres) on the separate system.

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GENERAL VIEW OF SEWAGE PURIFICATION WORKS OF WILMERSDORF, GERMANY.

As planned and constructed, the sewerage system takes care of 1,650 liters per second (436 gals.)

All the sewage is pumped against a head of about 220 ft. The pumping station contains four Körting double-acting, two-cycle gas engines, with which the sewage pumps are direct connected. Each revolution of a pump lifts 200 liters (52.8 gals.) of sewage against a pressure head of 67.4 m. (221 ft.), and the pumps make from 30 to 90 r. p. m. Producer gas is ordinarily used in the engines, but during heavy rains illuminating gas is substituted. The pumping station was erected at a cost of $350,000. A feature of it is the large rectangular, covered sand or grit chamber through which the sewage passes before going to the pump sump. Bar strainers are provided to keep larger suspended matters from entering the sump.

No land suitable for sewage irrigation could be found at any reasonable distance from Wilmersdorf. At the suggestion, therefore, of the Royal Sewage Experiment Station, in Berlin, the municipality of Wilmersdorf caused an experimental biological sewage purification plant to be erected at Charlottenburg, in 1903, which was kept in operation for nearly two years. The results obtained were summarized in a report, issued in March, 1905, which stated that the efficiency of the biological method experimented on had been satisfactory in both summer and winter weather.

It was therefore decided to purify the sewage by open septic tanks or sedimentation basins, by trickling or percolating filters, and by subsequent filtration through gravel beds. This was approved by the Royal Sewage Testing Commission. Land was, therefore, purchased for sewage disposal purposes, consisting of 34 ha. (84 acres), at a cost of $30,000, but this was added to, as stated further on.

The force main from the Wilmersdorf pumping station necessarily passed through the suburbs Schmargendorf, Zehlendorf and Teltow, and since all these places lacked sewerage facilities, an agreement was reached in March, 1905, by which the pumping main and the sewage treatment works were to be used jointly. The pumping main, which was of cast iron, 16.8 kilom. (10.44 miles) long and laid in duplicate, was gradually increased from 850 to 1,050 mm. (33 to 41 ins.). The cost of the pumping main was $900,000. Although the pipe had been tested to 300 lbs. per sq. in., 14 breaks were found in the main after it was laid. Additional land, to the amount of 33 ha. (81.5 acres) had also to be bought, so that the entire disposal area now comprises 67 ha. (165.6 acres), which has cost $125,000.

The future population to be provided for was 631,000, distributed as follows: Wilmersdorf, 328,000; Schmargendorf, 78,000; Zehlendorf, 150,000; Teltow, 75,000. For the present the system provides for only 200,000 persons, at 28.5 gals. of sewage per capita per day, or a total of 5,700,000 gals. (21,600 cu. m.), excluding rainfall.

The recommendations of the Royal Sewage Experiment Station as to the proportioning of

the plant in relation to dry weather flow, with the daily capacities provided accordingly, were as follows:

	Per cent.	U. S. gallons.	Cubic meters.
Preliminary sedimentation basins.	50	2,850,000	10,800
Trickling filters	200	11,400,000	43,200
Final filters	25	1,425,000	5,400

Fig. 1 shows a general plan and a profile of the sewage treatment works and Fig. 2 is a general view of the works. The sewage is delivered through the pump or force main into a distributing well, which will be the central point of the works, when extended. From the well it flows by gravity through masonry conduits into a group of six sedimentation basins. These are practically open septic tanks, and the six basins, which are located in two rows, are inter-connected by overflows. The sewage passes through these basins successively, and from the last basin the partly clarified sewage flows into a gathering chamber or gallery, and from here intermittently to the trickling filters. After passing through the filters the sewage flows into another series of six sedimentation basins, and finally it passes purified through an outfall to the Teltow Canal, or it may be further purified in Chorley sand filters.

DISTRIBUTING WELL.—This is located, as shown in the general plan (Fig. 1), in a central position. It is built of masonry and contains on the inside six sluice gates which will ultimately control six conduits, of which at present only two are built and in use. The two conduits now built conduct the sewage to the preliminary sedimentation basins.

PRELIMINARY SEDIMENTATION BASINS.—The object of these is to free the sewage from floating and suspended impurities by reducing the velocity of the sewage flow through them. Each sedimentation basin has an average depth of 3.5 m. (11.5 ft.), an area at the bottom of 430 sq. m. (4,628.5 sq. ft.) and at the top of 730 sq. m. (7,857.7 sq. ft.). The capacity of each of the basins is approximately 2,000 cu. m. (70,628 cu. ft.) or 529,710 U. S. gals.

The sloping sides and the bottoms are covered with concrete. The bottom of each basin has a slope to a semi-circular channel, molded in concrete, and located in the central axis of the basin. The channel is provided with an outfall drain, closed by a gate, which is intended for the removal of the accumulated sludge.

The basins are inter-connected by means of overflow channels, so arranged that normally the sewage must pass successively through all six basins of one group, before it is distributed onto the trickling filters. Near the overflows to each basin are located slanting baffle boards, built of Monier concrete slabs, the object of which is to hold back floating substances and to promote the sedimentation of the sewage sludge.

If one basin is cut out for cleaning purposes, the sewage is made to pass through the other five basins of the group, and in that case the cubic capacity of each of these may be increased by placing weir boards, 0.5 m. (19.6 ins.) high, in the overflow channels.

It is intended that this cleaning should be done during the night time, when the sewage flow becomes reduced in volume. At present it is not the intention to cover the open basins, but provision has been made in the concrete for supporting covers, if found later on to be required.

GATHERING AND DISTRIBUTING CHAMBER.—From the last sedimentation basin the partly clarified sewage is delivered into a covered gathering chamber of 75,000 liters (20,000 gals.) capacity. This has a surface area of 140 sq. m. (1,506 sq. ft.). The chamber (see Fig. 2) is emptied by means of an intermittent automatic device of special construction, which discharges a limited amount of sewage through a pipe, 900 mm. (35.4 ins.) in diameter, and through a network of distributing pipes, gradually reduced in size, to the trickling filters.

The outlet pipe is closed by a vertical cylindrical valve, which is balanced by suspended weights. When the gathering chamber has become filled to a certain point, sewage flows through an overflow into one of the suspended buckets, and this action opens the vertical valve on the delivery pipe. When a certain amount of sewage has run out, a float valve opens the bottom of the bucket, thus emptying the same. The valve on the delivery pipe then closes action begins anew. The amount of sew charged at each operation of this auto vice can be varied to suit the condition action is entirely automatic, but will re course, occasional inspection and regulati

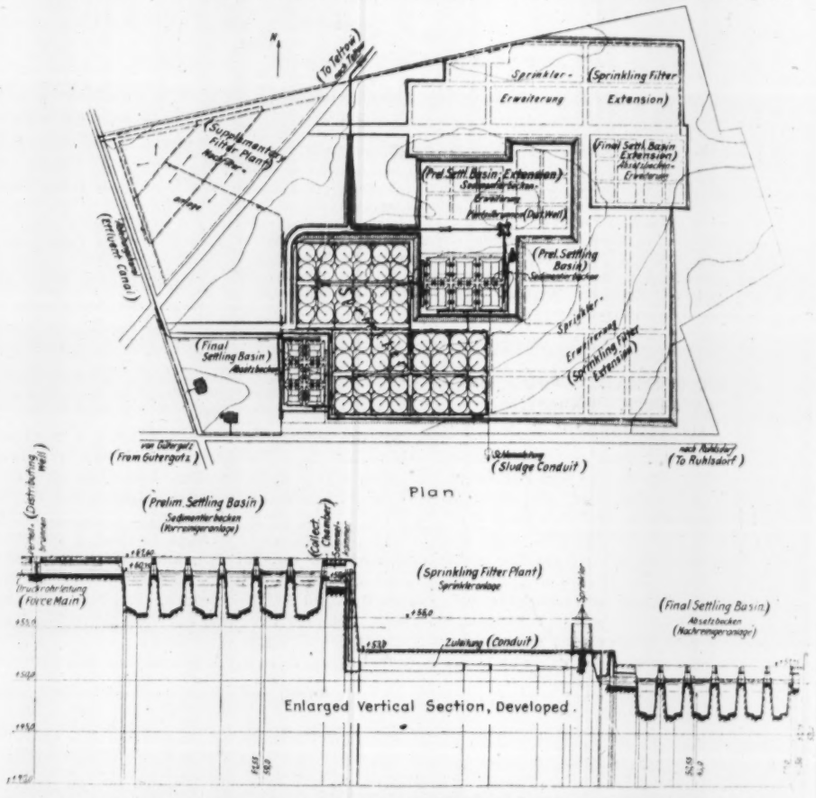


FIG. 1. GENERAL PLAN AND PROFILE OF SEWAGE PURIFICATION WORKS, WILMERSDORF, GERMANY.

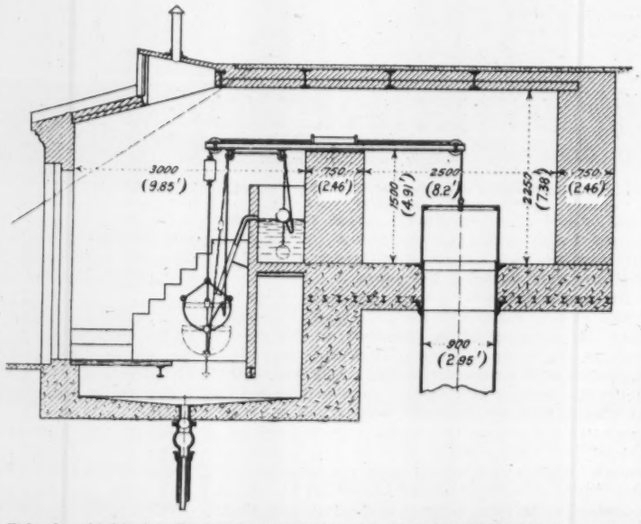


FIG. 2. SECTION THROUGH RECEIVING AND AUTOMATIC DOSING CHAMBER, PLACED BETWEEN PRIMARY SETTLING BASINS AND TRICKLING FILTERS, WILMERSDORF, GERMANY.

cylindrical valve is open at the top and answers as an overflow, so that in case the automatic action should be interrupted, there will be no overflowing of the sewage outside the distributing chamber. The number of discharges is counted by an ingenious automatic registering apparatus.

TRICKLING FILTERS.—Trickling filters were chosen in preference to contact beds because "experience has shown that these are more efficient where plenty of difference in elevation is available." The topographical features (see profile, Fig. 1) were particularly favorable for a system of trickling filters. Another important reason why trickling filters were preferred was that their efficiency, as regards volume of sewage to be dealt with, was found in the previously-mentioned experiments at Charlottenburg to have been higher than that of contact beds.

A view of the trickling filters while in action is shown by Fig. 3. The rotary sprinklers were chosen in preference to fixed nozzles, jets or distributing channels "because they effect the most uniform distribution of the sewage." The rotary sprinkler decided, of course, the circular form of the trickling filters.

For the present population of 200,000 persons, 56 trickling filters were provided. Each filter is 20 m. (65.6 ft.) in diameter and 2.5 m. (8.2 ft.) high, and has therefore a gross volume of 785 cu. m. (27,720 cu ft.).

The trickling filters are built on a bed of concrete (see section Fig. 4), which slopes from the center to the circumference. Upon the bed are placed double rows of hollow fireproofing blocks with open joints, to provide good drainage for the beds, and to prevent any accumulation of putrefying organic matter. An open circular concrete trough all around the filter leads the purified sewage into covered drainage pipe channels connecting with a main conduit.

The outer portions of the filters are built up of very coarse coke, on a slope of 4 to 1, with no other retaining wall. The filters are aerated

by means of eight radial vitrified pipe channels, located at a height of 1.25 m. (4.9 ft.) from the bottom. *Standing entirely free, surrounded on all sides by air, these filters are much better adapted for bacterial sewage purification than if they were placed below the surface level.*

Of the 66 trickling filters, 51 are built up of coke, 14 of large broken clinkers, 1 of limestone and 1 of broken concrete. The coke used varies in size from "that of a man's fist to that of a man's head." The results obtained in purification are watched and compared, with a view of determining the best and cheapest filter material, to be used in the future enlargement of the sewage disposal plant.

FIG. 3. VIEW OF TRICKLING OR PERCOLATING FILTERS IN ACTION, WILMERSDORF, GERMANY.

ROTARY SPRINKLERS.—The rotary sprinklers are arranged in the center of each trickling filter bed. They consist essentially of vertical stand-pipes (see Fig. 5) closed at their upper ends, which are connected with the lateral supplies to the filters in a watertight manner by means of connecting pieces, reaching to about 2 m. (6.5 ft.) above the top of the filter. These have openings through which the sewage passes to the sprinkler head. The latter is connected a little above the top of the filter with the stand-pipe. It consists of a circular vessel, about 30 cm. (12 ins.) in height, with bottom and double sidewalls, and has a mercury seal. Into this seal dips the bell of the sprinkler, to which are connected four horizontal pipe arms, each 4 ins. in diameter, and about 9.5 m. (31.2 ft.) long. These pipe arms have numerous perforations, each 3 mm. (3-25 in.) in diameter, in one of the sides, at right angles to the pipe axis, and the combined area of the holes is about 25% larger than the area of the pipe. The holes are set closer together toward the outer end of the arms. The outer ends of the pipe sprinklers are provided with removable caps, so that obstructions in them may be removed. The sewage issues in horizontal sprays, when the filter is dosed. All parts of the rotary sprinkler are made of cast iron, except the horizontal pipe arms, which are constructed of Mannesmann tubes. Special care has been taken to guard against the freezing of the sprinklers, to provide for the cleaning of the pipe arms, and to avoid any undue straining by wind pressure.

The dosing of the trickling filters is *intermittent*. When they were first put in operation, the sewage from only 66,000 persons flowed to the works, and the interval between discharges of the automatic charging device was 15½ minutes, the sprinkling being done in ½ minute, and the other 15 minutes being intended as a period of rest for the filter. This time was changed, when the plant came to be in full operation, to 5½ minutes.

Suitable provision is made on the main sewage conduit from the distributing chamber, and on the laterals to the sprinkling filters, for a large number of slide or sluice valves, in order to regulate and control the sewage flow to each filter. The best and most favorable opening of the valves is thus determined by actual experiment.

These valves also enable the complete throwing out of commission of any of the filters, and they also permit of experimenting with one or the other of the group of filters, to ascertain the maximum volume of sewage which a filter is able to receive without a reduction in purifying effect.

FINAL SEDIMENTATION.—The effluent from the trickling filters is carried to a second group of sedimentation basins, shown by Fig. 6, which are intended to effect a further clarification of the sewage. There are six of these basins provided, each having a bottom area of 200 sq. m. (2,153 sq. ft.), a top area of 400 sq. m. (4,306 sq. ft.) and an average depth of 2.8 m. (9.2 ft.). The capacity of each basin is therefore approximately 5,000 cu. m. (176,570 cu. ft.) or 1,324,275 gals. The final sedimentation basins are arranged and constructed in much the same manner as the primary basins already described.

SAND FILTERS.—The sewage, thus purified, may be either discharged into an outfall sewer, leading to the Teltow Canal, or else it may be given still further treatment, on Chorley gravel and sand filter beds. The object of the Chorley filters is to intercept the suspended products of the trickling filters as well as the sewage bacteria. These have, for the present plant, an area of 28,000 sq. m. (301,392 sq. ft.) or in the proportion of 0.75 cu. m. (198 gals.) of sewage to each sq. m. (10.764 sq. ft.) or at the rate of about 19 gals. per sq. ft., or approximately 825,000 gals. per acre. These filters have sides and bottoms of concrete and are arranged in four irregular-shaped fields. The depth of these filters varies from 0.60 to 0.8-m. (23.6 to 31.5 ins.). They are underdrained, and the drains are gathered into outfall pipes leading to the above-mentioned double conduit, of 900 mm. diameter (35.5 ins.), built of concrete pipes, which discharges into the canal.

All around the purification works, and between its various parts, well-finished roads and paths are provided to render every part of the plant accessible. Shrubs and trees are planted to protect the works against wind, snow drifts, etc.

REMOVAL OF SLUDGE.—The removal of the sludge from a sedimentation basin is accomplished as follows: The liquid sewage is first removed by means of a centrifugal pump, operated by a boiler and engine mounted on wheels, and discharged into the adjoining basin. The sludge is then siphoned out by means of cast-iron pipe conduits and discharged into open ditches leading to areas on a lower level, where it is deposited, spread out, and covered with a layer of sand. There are 13 sludge basins, each of about 27,486 sq. ft. area, giving a total area of about 8.2 acres. The average depth of these basins is 1.30 m. (4.25 ft.), thus giving a total sludge capacity of 30,000 cu. m. (1,059,420 cu. ft.) It is expected that the dried sludge may be made available for agricultural purposes, but the very large areas provided will answer for the disposal of the sludge for a long time in case this expectation is not realized

BUILDINGS.—A building has been provided, containing offices, a chemical laboratory, and the living rooms of the inspector in charge of the plant. Another building provides homes for the families of four laborers employed in the work.

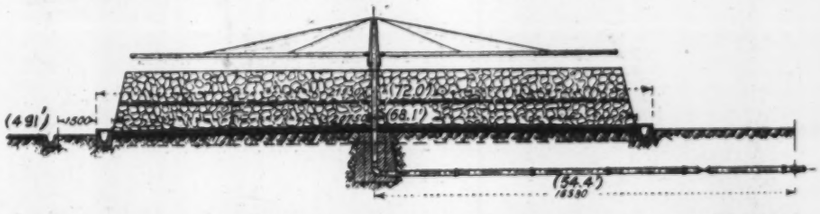


FIG. 4. SECTION THROUGH TRICKLING OR PERCOLATING FILTER, WILMERSDORF, GERMANY.

The final effluent or outfall conduit has a length of 3.3 kilom. (2 mi.). It consists largely of concrete pipes, 1.0 × 1.5 m. in size (39 × 60 ins.). This discharges into a branch feeder of the Teltow Canal.

The present plant occupies about 11 ha. (27.18 acres), whereas the entire available area, bought up by the several co-operating communities, amounts to 67 ha. (165.56 acres). If 22 additional ha. (54.36 acres) are devoted to more sed-

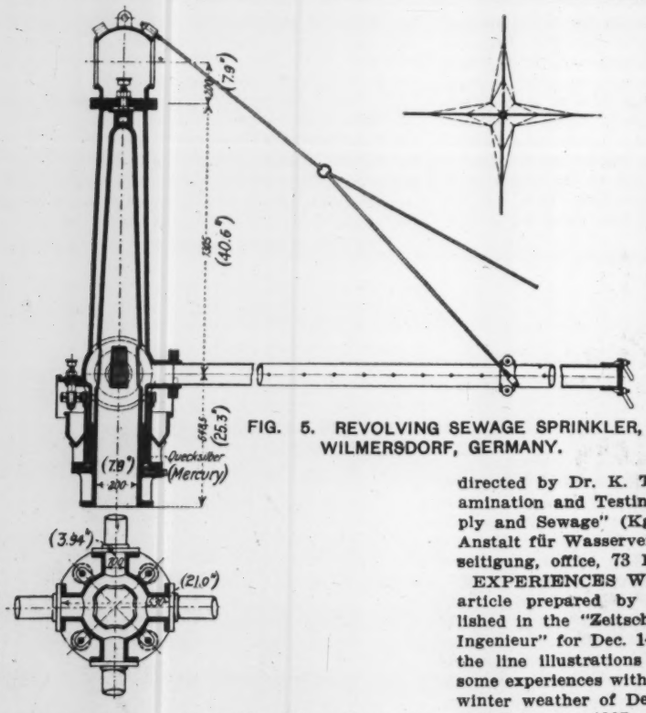


FIG. 5. REVOLVING SEWAGE SPRINKLER, WILMERSDORF, GERMANY.

imentation basins and trickling filters, there will remain about 34 ha. (84 acres) available for sludge disposal.

VISIT TO THE WORKS.—The entire works were planned by and constructed under the superintendence of Baurat Müller, of Wilmersdorf, to whom the writer is indebted for courtesies extended to him. The work was given out by contract, and required about one year to build. The sewage disposal plant was first put in use on Sept. 1, 1906.

When the writer of this article saw the plant, in February, 1907, it had been in operation only a few months, hence no records of results obtained by the biological purification were available. The writer visited the plant on a very cold day, the thermometer outdoors registering about 14-15° R. below zero (from 0° to minus 3° F.). The roads were covered with deep snow, yet there was very little difficulty experienced with the operation of the rotary sprinklers. There was some ice formed on the top and sides of the trickling filters, but not sufficient to prevent the sewage from passing through them. No odor was noticeable at the preliminary sedimentation basins, and but a trifling odor at the trickling filters.

The writer's attention to this modern plant was directed by Dr. K. Thumm, of the "Royal Examination and Testing Institute for Water Supply and Sewage" (Kgl. Versuchs-und Prüfungs-Anstalt für Wasserversorgung und Abwasser-Beseitigung, office, 73 Kochstrasse, Berlin).

EXPERIENCES WITH THE PLANT.—In an article prepared by Baurat Müller, and published in the "Zeitschrift des Vereins Deutscher Ingenieur" for Dec. 14 and 21, 1907, from which the line illustrations of this article are taken, some experiences with the plant during the severe winter weather of December, 1906, and January and February, 1907, when the thermometer outdoors registered as low as —21.5° C. (—6.5° F.) are related.

Notwithstanding the fact that the sewage, as it reached the trickling filters, had a temperature of 45.5° C. (42° F.), the small (3 mm.) holes in the rotary sprinklers closed up with ice, so that it became necessary to enlarge all holes to 10 mm. (nearly 0.4 ins.). Since this was done there has been no further trouble from ice.

The open circular channels around the filters also became partly obstructed with ice and snow; they were subsequently raised and covered with concrete slabs (as shown by Fig. 4).

The total cost of the plant, including pumping main, was 6,600,000 marks ($1,650,000). The running expenses at present are 16,000 marks or $4,000 per year, of which more than one-half is for salaries of employees. Reduced to the present population connected with the sewer system, this is 0.2 mark or about 5 cts. per capita per year, which amount will be reduced when the population contributing to the plant increases over present figures.

TESTS.—The Royal Sewage Testing Commission of Berlin inspected the plant on May 3, 1907, and took a number of samples of the raw sewage and of the effluents from the various beds for physical, chemical and bacteriological analyses, and the report on their tests is given in the above-named German paper. The substance of the report is that the purification effected was quite satisfactory, and that the water in the Teltow Canal showed no difference in chemical composition above and below the discharge of the sewage outfall.

At the plant some bubbling up of gases was noticed in the preliminary sedimentation basins, much like that in open septic tanks, but very little sewage odor was noticeable. Only the first and second basins had a floating scum, of from 3 to 4 cm. thickness (1.2 to 1.6 ins.); the other basins had no scum whatever. This observation was made just two months after the first cleaning of the basins. In the depositing basins, very little floating scum had formed.

ARCHED SPLICE-BARS FOR RAILS have been used in an experimental way for two years past on the railway system of Austro-Hungary. They are made by bending ordinary fish-plates or angle-bars hot, in a vertical plane, convex on top and concave on bottom, to a middle deflection of about ⅛-in. The bars are then driven into place with a hammer and are bolted up as usual. The bars press against the bottom of the rail head at the joint, while their ends rest on the foot of the rail. In this position they force the joint upward a slight amount; as a wheel approaches the joint, the loaded rail is forced down, bending the splice-bars, and this lowers the other rail by the same amount. Thus, so long as the load of the wheel does not exceed the spring effect of the splice-bars, the joint remains flush and no hammering occurs. Maintenance reports are said to be quite favorable to this type of joint. The arched splice-bars are made from ordinary splice-bars which have worn too narrow. Mr. M. Spitz, engineer of maintenance-of-way, describes the joint in the "Organ fur die Fortschritte des Eisenbahnwesens in Technischer Beziehung" of Jan. 15, 1908.

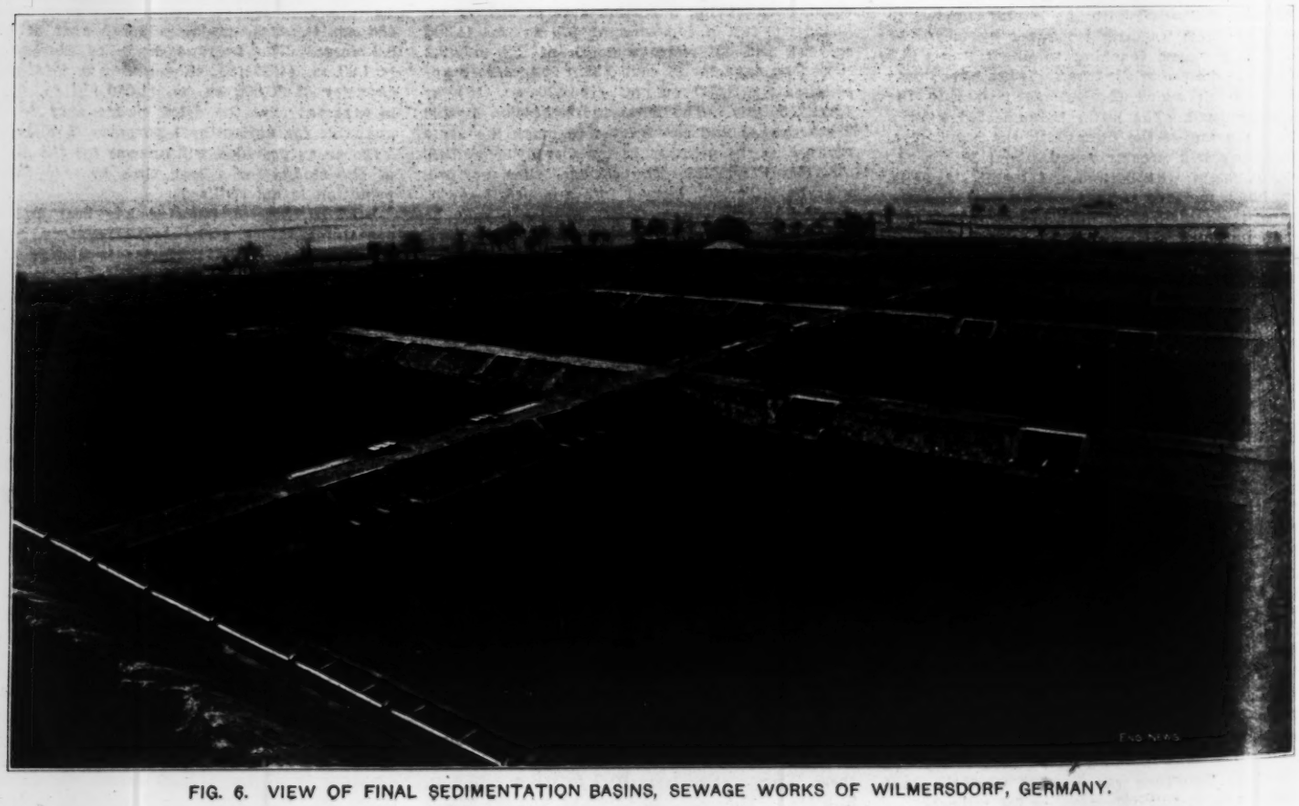


FIG. 6. VIEW OF FINAL SEDIMENTATION BASINS, SEWAGE WORKS OF WILMERSDORF, GERMANY.

STEEL CONSTRUCTION FOR LONG SPAN FLOORS IN THE CHICAGO ATHLETIC ASSOCIATION BUILDING.

The new building of the Chicago Athletic Association, forming an annex of the main building at 125 Michigan Ave., is a 12-story steel frame structure having three basements below the street grade. It is of interest in that no interior columns are used, this arrangement being adopted in view of the purposes for which the building is to be used. In plan it is about 48 × 80 ft., and in the longer sides the wall columns are spaced about 19 ft. 6 ins. c. to c. In the north end there are two intermediate columns, forming three panels 14 ft. 11 ins. c. to c. In the south end, there is only one intermediate column, on account of the connections with the north side of the main building, and this forms two panels of 19 ft. 2 ins. and 25 ft. 7 ins. c. to c. of columns. All the columns are of box section, built up of a pair of channels (placed with the flanges outward), having continuous cover plates riveted to the flanges. Between these columns are plate girders in the end and side walls.

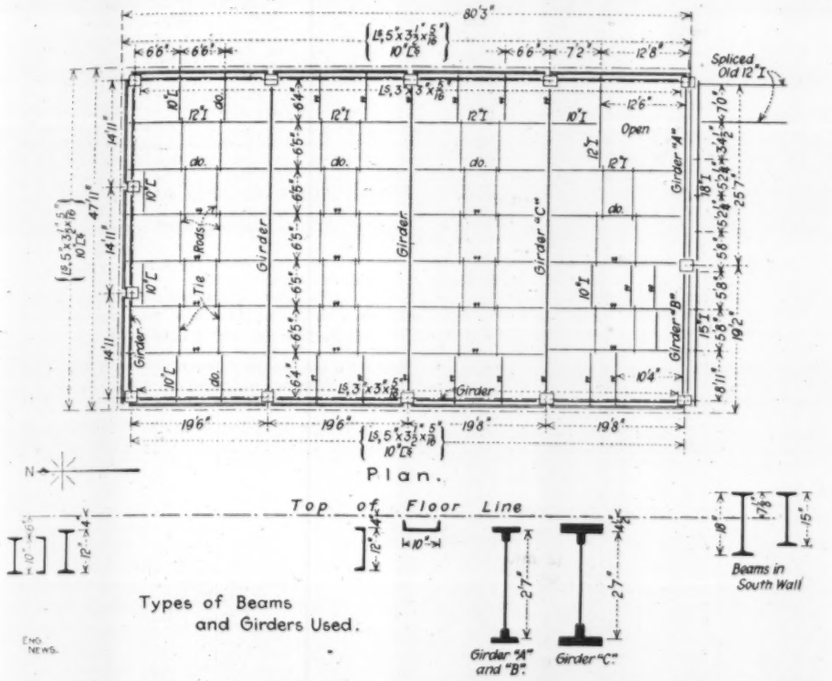


FIG. 1. PLAN OF STEEL FRAMING OF THE CHICAGO ATHLETIC ASSOCIATION BUILDING, CHICAGO.

Richard E. Schmidt, Garden & Martin, Architects.

The long spans made the use of the ordinary I-beam floor framing impracticable, and from the plan, Fig. 1, it will be seen that three lines of plate girders span the full width of the building. Between them are lines of 12-in. I-beams for the floors. One of these girders, 43 ft. 3⅛ ins. long between the columns, is shown in Fig. 2. It has a ½-in. web plate 30 ins. deep, chord angles 6 × 4 ins., and 13-in. cover plates. Angle brackets are provided for the I-beam stringers of the floor system. The end of the web plate is fitted between two splice plates which are attached to the face of the column by vertical angles 8 × 8 ins., while the top and bottom chords fit between horizontal angle brackets. In Fig. 3 is shown a detail of the end connections, which were designed specially to secure rigidity. It will be seen that not only the vertical connections riveted to the inner face of the column, but that they are bolted through to the outer face.

The plate girders of the short spans at the north end are 13 ft. 9 ins. long between the faces of the columns. Each girder has a single ⅜-in. web plate 42 ins. deep. The chord angles on the inner side are 4 × 3 ins., while those on the outer side are 5 × 3 ins. Each inside stiffener angle carries a gusset plate with angle brackets at the bottom for the connection of the angle brackets on the I-beam stringers. The outside stiffener angles carry larger triangular gussets with attachments for the shelf beams which support the masonry of the enclosing walls. The general construction of these girders is shown in Fig. 4. It will be seen that the end of the web is spliced to a large connection plate attached to the column by vertical angles; the chords fit between horizontal angles riveted to the connection plate. Fig. 5 shows the erection in progress at this end of the building.

The architects for the building were Richard E. Schmidt, Garden & Martin, of Chicago, and the steel construction was designed by them.

The sub-basement is adjacent to the old 10-story club building, with its boilers adjoining a party wall and a plunge tank 30 × 60 ft. within 20 ft. of the line. Before the basement could be excavated, it was necessary to remove the solid masonry wall from foundation to roof, replacing it by shores and a sheathing partition, and transferring the load to the new columns which were then standing on the concrete caissons in the lagged walls. The old boiler flue was part of the old wall, and before this could be torn down the old boiler breeching above grade had to be temporarily connected with the smoke inlet of the stack (considerably below grade) in the new building by means of a deeply dipping breeching. The entire power plant in the old building was abandoned and a new plant built in the annex, also under the supervision of the architects, with Mr. S. G. Hobert as mechanical engineer in charge.

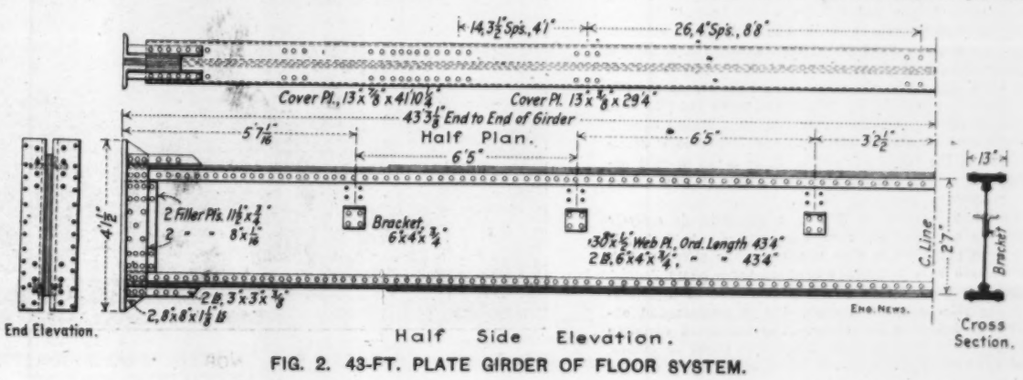

14, 3½" Spa., 4'
26, 4" Spa., 8'8"
Cover Pl., 13" × ⅞" × 41'10½"
Cover Pl. 13" × ⅞" × 29'4"
43'3⅛" End to End of Girder
Half Plan.
2 Filler Pls. 11½" × ¾"
2 - - 8" × 7/16"
Bracket, 6" × 4" × ¾"
30" × ½" Web Pl., Ord. Length 43'4"
2 Pr. 6" × 4" × ¾", - - 43'4"
2 Pr. 3" × 3" × ⅜"
2 Pr. 8" × 8" × 1⅛"
C. Line
Bracket
End Elevation.
Half Side Elevation.
Cross Section.
ENG. NEWS.

FIG. 2. 43-FT. PLATE GIRDER OF FLOOR SYSTEM.

A HEAVY CONCRETE PILE FOUNDATION.

The following interesting account of a foundation formed of cast and driven concrete piles was recently presented by Mr. Charles R. Gow, Assoc. M. Am. Soc. C. E., to the Boston Society of Civil Engineers and reprinted in the Journal of the Association of Engineering Societies for October, 1907:

By far the most interesting case of concrete pile work we have yet handled is that of the Milton car barn foundation for the Boston Elevated Railway, on which we are now working. The site of the work, covering a little less than an acre, is one of the most peculiar ground formations ever met with in our experience. Surrounded on all sides by ledge, the lot itself is a deep deposit of semi-fluid mud and quicksand extending to a maximum depth of 40 ft. The mud and sand are interspersed with what appear to be floating masses of hard pan, and at times beds of gravel overlying the quicksand are encountered. There seems to be no particular order or relation between the different classes of ground, and to further complicate matters the ledge bottom itself is so irregular that variations of 10 ft. in depth sometimes occur in a few feet distance. As the entire ground is thoroughly saturated with water, wooden piles would have been sufficient except for the possibility of future drainage if the ledge divide was ever penetrated. Concrete piles built in place were considered dangerous on account of the extreme depth and the unstable surrounding soil. The only alternative was the driving of cast piles, and this was the system finally adopted. Soundings were made at the location of each pile. A ½-in. gas pipe was coupled to a water hose fed by city pressure and jetted down to ledge. In this manner the exact depth from the surface of the ledge was determined for each location and a pile cast and numbered to correspond.

The proposed building covers an area of approximately 37,000 sq. ft.; 414 piles are required, ranging in length from 1.5 to 40 ft. All piles up to 6 ft. are built in place in a wooden form. A low wall of concrete capping the outside lines of piles supports the building walls, while interior loads are, for the most part, carried on columns resting on a single pile. Each interior pile is capped with a block of concrete 2 ft. square, in the top of which is set a dowel to take the wooden column. To prevent any lateral motion in the soft mud, the original plans contemplated the use of concrete tie beams in four directions. Owing to the difficulty of trenching for the beams in the semi-fluid mud, and the absence of any foundation on which to lay the concrete, this feature of the construction was changed at our request to the use of a 6-in. slab of concrete covering the entire lot and surrounding the pile heads. This slab rests upon a 6-in. bed of cinders overlying the mud. It is reinforced with poultry netting crossed in two directions. As the slab floats on the mud, precautions were taken to break its bond around the piles and against the walls by the insertion of tarred paper in order that it might settle evenly if at all.

The piles were cast with a square section 13 ins. on a side, and since they were to act as bearing piles no taper was given them. The mixture was a 1:2.5:4 concrete. Clinton electrically welded wire cloth was adopted as a reinforcement, having ¼-in. longitudinal wires 3 ins. on centers. This reinforcement was bent to such shape as to make a continuous reinforcement 2 ins. inside the face of the piles on all four sides. A line of tin speaking tube 1½ ins. in diameter was built in at the center of the pile to admit water for jetting purposes. This tube was stopped about 10 ins. from the head of the pile and, by means of an elbow and threaded nipple, projected through the side of the pile to allow of attaching the pressure

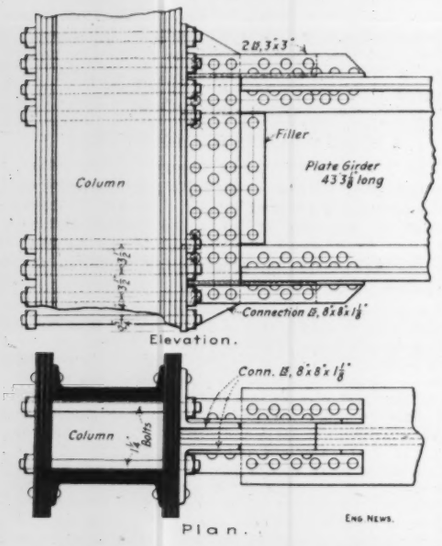


Fig. 3. End Connections of Floor Girders.

hose. The piles are handled with guyed derricks and inserted in a timber guiding frame containing a pair of driving gins. As soon as it is properly centered the jetting hose is attached to the nipple, and water, supplied by a steam pump at 100 lbs. pressure, is forced through the interior tube and out of the bottom of the pile. It has sometimes been found expeditious to churn the pile up and down during sinking by means of the derrick. This action appears to thoroughly loosen the surrounding ground and allows a freer escape of the material below the pile.

As stated, at intervals all over the lot thin layers of hard pan are encountered, apparently floating in the mud and sand. It has been necessary to drive the pile through these masses when encountered. Much apprehension was felt as to the possible damage which might result from the driving of these piles. A wooden follower has been used, resting on the pile head, and a 2,800-lb. hammer dropped from as high as 20 ft. has failed to produce any apparent injury. In the case of one pile the sounding pipe used in determining the necessary length of pile had penetrated a narrow crevice between two boulders and the pile was cast to the length so found. Upon attempting to drive this pile, the space between the two boulders proved to be too small to admit it. Not knowing what the obstruction was, the foreman attempted to drive through it. Three hundred blows of the 2,800-lb. hammer dropping 12 ft. were given without appreciable penetration, and rather than cut off and waste about 6 ft. of undriven pile, it was determined to pull the pile out and replace it with a shorter one. Upon withdrawing the pile, it was found to be perfectly sound and uninjured, except that the point had been slightly worn away on each side where it had rested against the two boulders. Each pile is finally driven until it brings up firmly on the ledge.

The extreme length of many of the piles introduced the serious question of how best to handle them and avoid breakage. It was found that up to 30 ft. in length they could be picked up by the end without producing any undue strains, but when over 30 ft. they almost invariably cracked in the middle. To prevent this action, four angle irons were at first used strapped to the four corners of the pile by means of iron clamps. This method was effective, but the time required in placing and removing the irons rendered it impracticable. A simpler device was finally adopted which has allowed the handling of piles up to 40 ft. in length without damage. A long chain is used, one end being wrapped around the pile near the center, while the other end is similarly wrapped near the top end; the hook of the hoisting fall is hooked into the long loop of the chain, and as the pile is hoisted the hook slips along the chain toward the top as the pile is gradually upended. By this means, while the pile is in a horizontal position, the strain is applied almost equally at the two points of attachment and prevents undue stresses at the center of length. Once in an upright position, of course, no further precautions of this nature are necessary.

The time required in driving a pile depends entirely upon the nature of the ground penetrated. A 35-ft. pile has been put down in nine minutes, while piles one-half that length have sometimes required three hours.

In some cases difficulty was encountered in maintaining the pile in exact location, due to underground obstruction deflecting its course. The maximum variation of this nature thus far noticed has been about six inches, and fortunately has occurred under walls where the objection is slight as compared with its possible occurrence under columns, in which case a single pile supports the concentrated load.

This work was started late in November of last year. The early and severe freezing spells of that time caught us unprepared, with the result that about 75 piles were badly frozen. A thick covering of hay proved inefficient, as did also lines of steam pipes under the hay, spaced 10 ft. apart. Many of the piles were frozen before taking an initial set, and all of them before final set. Work on casting and then suspended until a shed could be constructed in which to cast the remainder. All attempts at protecting the frozen piles were abandoned and they were left to their fate, suffering alternate freezing and thawing throughout the winter. Late in January one of these piles was sent to the Watertown arsenal thawed out, and immediately thereafter tested for crushing strength. It failed at 60 tons, or 710 lbs. per sq. in. This test was deemed sufficient by the building department to warrant the condemning of the entire lot of frozen piles, but at our request a second sample was selected at random from the frozen lot and, accompanied by one of equal length taken from the lot cast under cover, was sent to the arsenal for a second test. This time the frozen pile was allowed to remain in a warm room after thawing for about 4 weeks before testing. It failed at 236 tons, or 2,800 lbs. per sq. in. The unfrozen sample failed at 241 tons, or 2,852 lbs. per sq. in. It would appear, therefore, that the frozen pile recovered practically all of its strength the freezing action was permanently remo this lot of piles have since been driven. In the extreme ends of the frozen piles app slightly disintegrated. In such cases we ends exposing the reinforcement and recast of the piles thus repaired were driven wit without injury to the new heads. In the of these piles the head was shattered when the pile was within 3 ft. of grade. A new head was cast in place, the pile allowed to stand for a week, and it was then successfully driven to grade.

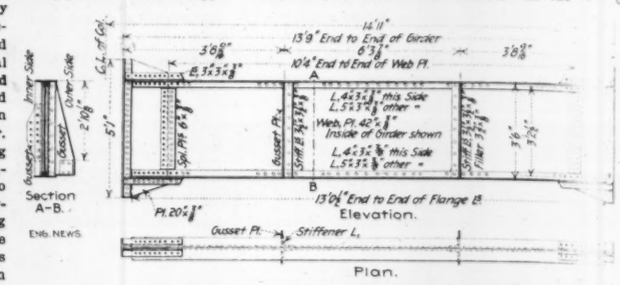


FIG. 4. PLATE GIRDER OF END PANEL.

Some of the piles in this work have been successfully driven through material that the ½-in. sounding jet penetrated with the greatest difficulty, and if tapered they could probably be driven through any material that a wooden pile would penetrate.

As the work was suspended for the winter after casting the piles, no information was obtained as to how long after casting the piles could be handled and driven.

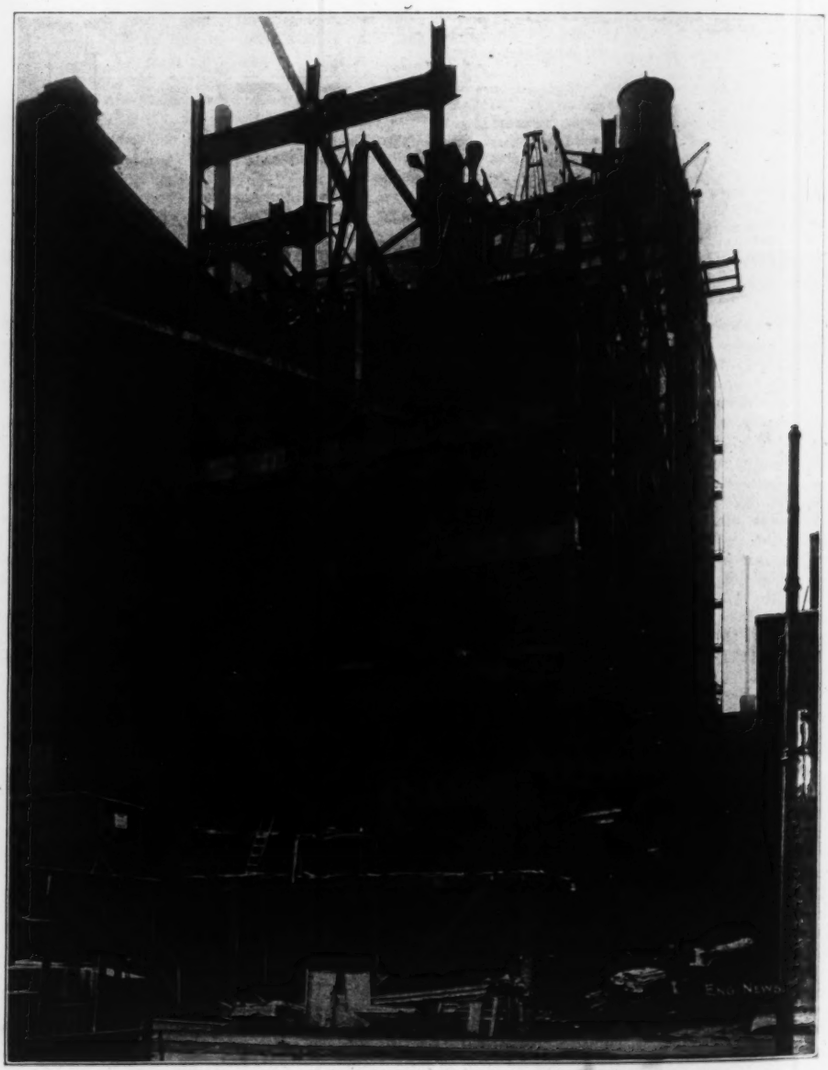


FIG. 5. VIEW OF NORTH END OF STEEL FRAME CONSTRUCTION, CHICAGO ATHLETIC ASSOCIATION BUILDING.

It is possible that if cast in warm weather they could be handled in two weeks without injury.

These piles, if built as designed, weigh 175 lbs. per lin. ft., and the longest ones, therefore, weigh about 3.5 tons. It may be readily understood that the handling of such a heavy load requires extreme care at all stages of the work. Owing to the fact that our piles were cast in many instances at a considerable distance from the point where they were to be driven, much time was lost in moving them to the driver. Another time we shall attempt to so lay out our work as to bring each pile within easy reach of the driving apparatus.

One important point to be considered in cases where the water jet method is contemplated is the displacement of soil which takes place owing to the jet action. This displacement in such soil as mud and fine sand appears to be something greater than the actual contents of the pile. This probably does not signify that voids have been left in the ground below, but rather that the disturbed soil has been altered in density, and a resulting shrinkage or subsidence may occur in the future as the material gradually returns to its original condition. An interesting feature of the Milton work in this connection has been the tendency many times for the water from the jet to reappear, not around the pile being driven, but in some cases around some other pile already driven, or perhaps through some old test pipe hole from 50 to 100 ft. away. Meanwhile the ground in the vicinity of driving has risen from one to one and one-half feet in elevation.

THE REPORT OF THE ROYAL COMMISSION OF INQUIRY ON THE COLLAPSE OF THE QUEBEC BRIDGE.

As already noted in our last issue, the Royal Commission instituted by the government of the Dominion of Canada to investigate the collapse of the Quebec Bridge has completed and submitted its report. We are pleased to be able here to present an abstract of this report. The bridge, it will be remembered, collapsed late on the afternoon of August 29, 1907, while about half completed, carrying down 85 men, of whom all but eleven were killed.* Two days later the Governor-General of Canada, upon the recommendation of the Minister of Railways and Canals, appointed a commission of three engineers to inquire "into the cause of the collapse of such bridge, and into all matters incidental thereto." Mr. Henry Holgate, of Montreal, Que., Mr. J. G. G. Kerry, of Campbellford, Ont., and Prof. John Galbraith, of the University of Toronto, were constituted a commission for this purpose. The commissioners were promptly at the site of the wreck and began their formal hearing a few days later; since that time they have been at work continuously.

The report, dated Feb. 20, 1908, is a bulky document. It comprises a brief statement of the Commission's purposes, procedure and essential findings, which makes up the formal report; about 1,000 pages of testimony; a great number of drawings, letters, and other exhibits; and, last but not least, 19 appendices which discuss in detail the various phases of the subject investigated. Of this matter we can, of course, reproduce only the most important portions, particularly as we have already given in extenso the important testimony of Mr. Theodore Cooper, Consulting Engineer for the bridge [Eng. News, Oct. 31, 1907]. and the officials of the Phoenix Bridge Company, the contractor [Eng. News, Nov. 28, 1907].

Objects of the Inquiry.

The Commission expresses the objective points of its work thus:

We understand that the commission instructs us to determine to the best of our ability the cause of the collapse of the Quebec Bridge and to thoroughly investigate any matters appertaining thereto which might enable us to explain that cause. We do not think that either the general design of the Quebec Bridge, the methods of financing the enterprise, the payments of money that have been made to or by the company or in its interest, or the obligations that the company has undertaken under various contracts and agreements have direct connection with the fall of the bridge. In the course of our investigations we have secured a large amount of general information on these and other matters not directly pertinent to the object of the enquiry, some of which has been introduced into this report so that the history of the undertaking might be more readily followed. We have not considered the scope of our enquiry limited concerning any matters which in our judgment related to the collapse of the bridge.

The inquiry was greatly facilitated by the ready co-operation of all concerned in the construction of the bridge.

Messrs. Cooper, Szlapka, Deans and Hoare especially have in our judgment made every effort in their power to assist us to establish the facts and have not attempted to spare themselves.

Some clearly contradictory statements are to be found in the evidence given in the early days of the enquiry by certain witnesses on whom the burden of the disaster fell. These statements may be attributed to the nervous tension under which the witnesses were laboring at the time.

The findings which resulted from the investigation were printed in full in our last issue (March 12, 1908, p. 288). They charge, among other things, that the immediate cause of the collapse was the failure of the lower chords of the anchor arm near the main pier; that these chords failed from defective design; that errors of judgment on the part of the designers are responsible for the defective design; that the unit-stresses allowed by the specifications were higher than usual and the specifications were not satisfactory or sufficient; that the dead load was assumed too low and the calculations were not afterward corrected, which error would have required the condemnation of the bridge even if the lower chords had been detailed properly; that the failure on Aug. 29 could not have been prevented, but that the loss of life might have been avoided; and that the present-day knowledge concerning the action of steel columns under load is not sufficient for designing *economically* such a structure as the Quebec Bridge. These findings agree closely with the conclusions expressed editorially in these columns after the disaster.

The appendices to the report contain much matter of interest to engineers. Their relation to the purposes and results of the investigation may be judged from the list of titles:

1. The evidence given before the Commission of Enquiry;
2. The exhibits filed with the Commission of Enquiry;
3. The history of the Quebec Bridge & Railway Company up to the end of the month of August, 1903;
4. The Phoenix Bridge Company;
5. The effect of financial limitations upon the design of the Bridge and a discussion of the evidence relating to this;
6. The history of the development of the specifications and a discussion of the evidence relating to it;
7. A description of the organizations and staffs maintained by the different Corporations interested in the erection of the Bridge;
8. A history of the development of the plans and of the methods followed in the designing offices;
9. Material, shop work and inspection;
10. Transportation and erection;
11. A discussion of the difficulties that arose during erection and of the events at the time of the collapse of the structure;
12. A description of the fallen structure;
13. An enumeration of the various full-sized column tests that have been made in America, accompanied by diagrams showing the results of these tests;
14. A comparison of the stresses in the several members of the main trusses computed from the Bridge as finally designed, with the stresses authorized by the specifications. This comparison was made by Mr. C. C. Schneider, Consulting Engineer, and is embodied in his Report to the Department of Railways and Canals;
15. A description of the various experimental researches that have been made in connection with the building of the Quebec Bridge and during this Enquiry;
16. A discussion of the theory of built-up compression members;
17. A comparison of the design for certain chords of the Quebec Bridge with those for similar members of other great cantilever bridges illustrated with outline drawings of the bridges and copies of the shop drawings of the chords;
18. A critical discussion of certain parts of the specifications;
19. Miscellaneous information.

In the following abstract of these appendices, the testimony itself is necessarily omitted. Reference may be made to those portions of it which we have already reprinted or summarized.

History of the Bridge Project.
(Appendices 3 and 5.)

The Quebec Bridge project goes back to 1852, when the late Gen. E. W. Serrell, Engineer of the Lewiston and Queenston Suspension Bridge, at the request of the City Council of Quebec, examined the locality and selected a bridge site practically identical with the present; a suspension bridge was then in view. This and later investigations and schemes led to no results, however, until in 1887 the Quebec Bridge Co. was incorporated by Act of Parliament to build and operate a railway and highway bridge across the St. Lawrence River. Further Acts of Parliament extended the time for the construction of the bridge, in 1891, 1897 and 1900. Subsidies were granted to the company in 1900; $1,000,000 by the Dominion Government, $250,000 by the Province of Quebec and $300,000 by the city of Quebec. In 1903 the name was changed to The Quebec Bridge & Railway Company, and the Government undertook to guarantee the bonds of the company up to $6,678,000 against a conveyance of the property; the time for completion was now fixed at July, 1910.

The Quebec Bridge Co., subsequent to 1888, had surveys of the St. Lawrence made by E. A. Hoare, and had the report of the latter, recommending three possible bridge sites between Quebec and the mouth of the Chaudière River, examined by Mr. Walter Shanly, who selected the third site, which is practically the present one. In 1897, after the Department of Railways and Canals had in 1891 also endorsed this site, the company finally adopted it.

In 1897 the Phoenix Bridge Co. was induced to draw up two plans for a cantilever bridge at this site (see J. S. Deans' testimony, Eng. News, Nov. 28, 1907). The second of these was made the basis of an application by the Quebec Bridge & Railway Co. to the Privy Council, early in 1898, for approval of the plans and site, which approval was granted. This plan showed a main span of 1,600 ft., 150 ft. above extreme high water for 1,200 ft. In the same year, 1898, Mr. Hoare, Engineer for the company, drew up specifications for the proposed bridge, in conjunction with the Department of Railways and Canals. These specifications were then considered only provisional, and were not used for the approach spans, but controlled all subsequent work except as they were modified by Mr. Theodore Cooper after he became Consulting Engineer to the company.

Invitations were issued in 1898 for plans and lump-sum bids for either a cantilever or a suspension bridge at the site. Seven designs and bids for the superstructure were received from five companies, and two bids for the substructure. Mr. Theodore Cooper was employed to examine and report upon these plans. He narrowed the comparison down to the cantilever designs of the Keystone Bridge Co. and the Phoenix Bridge Co., both of which he declared to be acceptable. The price of the latter was slightly the lower, and Mr. Cooper, on June 23, 1899, recommended it as the "best and cheapest" in accordance with his instructions.

Mr. Cooper at the same time advised that borings and test-pits be sunk to determine the best position for the piers, as the surveys up to that time were not sufficient to determine this; and he recommended that any contract should contain provisions for changing the length of the span, for modifying the carrying capacity of the bridge, and for increasing or decreasing the quantities.

No other competitive tenders were ever obtained. On Aug. 22, 1899, the substructure contract was awarded to Wm. Davis & Sons, of Ottawa, and the superstructure to the Phoenix Bridge Co. These awards were little more than a basis for the subsequent definite agreements. The financial condition of the Quebec Bridge Co. delayed definite action on the main bridge contract for four years.

Further borings were made in 1899, under Mr. Hoare, with the advice of Dr. Ami, of the Dominion Geological Survey. On their results Mr. Cooper, on May 1, 1900, recommended changing the span from 1,600 ft. to 1,800 ft., on the following grounds:

(1) The construction of the larger and deeper piers of the 1,600-ft. span will require at least one more year than those for the 1,800-ft. span.

(2) The contingencies of the construction of the deeper piers in the deeper waters, where they might possibly be subject in their incomplete condition to the heavy ice floes of the main channel, would be far greater than for the piers further inshore.

(3) The effect upon any future financing, by reducing

*A full description of the accident was given in our issue of Sept. 5, 1907, and this with supplementary matter published in succeeding issues may be read with profit in connection with the present report.

the time of construction and minimizing the real and imaginary contingencies.

A few days later this report was adopted and Mr. Cooper was appointed Consulting Engineer to the company.

A final contract was concluded with M. P. Davis, of Ottawa, for the substructure, in June, 1900. About the same time a provisional agreement for the superstructure was executed with the Phoenix Bridge Co., on the basis of certain unit prices named in the original lump-sum bid, modified by variations in the market price of plain steel between that time and the date of final order for each part of the bridge. The steel work for the anchorages was contracted for under this agreement, on June 15, 1900, the price of 4.516 cts. per lb. being fixed in accordance with the stipulation. Similarly, a contract for the approach spans was executed in December, 1900, at a price of 4.114 cts. per lb., erected and painted.

During 1901 and 1902, work was in progress on the main and anchor piers, and in 1902 on the approach spans. Some work was done at Phoenixville in making studies of the main bridge, awaiting the financial arrangements which would warrant active prosecution of the work. The substructure was completed late in 1902. In February, 1903, Mr. Cooper reported that the experiences of the preceding two years amply justified the change in length of main span from 1,600 to 1,800 ft.

The Government guarantee of the Quebec Bridge Co.'s bonds, obtained in 1903, cleared the way for undertaking the execution of the superstructure contract. Up to that time the Phoenix company had considered that payment was too uncertain for beginning work on the main bridge, and its endeavors to assist the Quebec company to market its bonds in the United States had failed. The enterprise bore no promise of early remunerative returns, and, being mainly a work of "national advantage," it was on a firm footing only when so declared and financially backed by the Dominion. Therefore, on June 19, 1903, a contract for the main bridge, drawn on the basis of the 1899 and 1900 agreements, was executed between the Quebec and Phoenix companies, in anticipation of the desired Government guarantee; but the Phoenix Company stipulated that this contract should not become effective until the legislation in question had passed and satisfactory arrangements made for the payment of the monthly estimates. These conditions were at last satisfied about the beginning of March, 1904, and the actual contract for the main bridge may be said to date from that time. The main unit prices were 5.60 cts. per lb. for trusses and bracing, 5.35 cts. for floor beams and stringers, 5.55 cts. for railings, etc., 5.75 cts. for bolts, etc., erected complete, but exclusive of duties.

Prior to this, however, the Phoenix Iron Co., which was to fabricate the steelwork for the Phoenix Bridge Co., had begun to equip its shops for the unusually heavy and large work of the bridge. It made extensive improvements in its bridge shops in the fall of 1902 and early in 1903, specifically for this work, and after the signing of the contract in June, 1903, it bought various large machines which would be required.

Furthermore, the work of designing was taken up promptly by the Phoenix Bridge Co., in July, 1903, having been practically at a standstill since the preparation of preliminary studies for an 1,800-ft. span called forth by Mr. Cooper's recommendation in 1900 of this length and its adoption by the Quebec company. The progress of the designing will appear more fully below.

The contract of June 19, 1903, and the attached letter of Mr. David Reeves (President of the Phoenix Bridge Co.) are given in full in the report. It may be useful to quote from these documents the clauses as to time of completion and mutual responsibility for accidents and delays.

The contract provides:

> Fifth. The said superstructure shall be completed by the 31st day of December, 1906, unless delayed or prevented by strikes, floods, or other causes beyond the control of the said party of the second part [Phoenix Br. Co.—Ed.], or unless the party of the first part [Quebec Br. & Ry. Co.—Ed.], shall fail to make any of the payments as hereinafter stipulated or to keep any of its covenants herein contained.
>
> The above date of completion is based upon the understanding that work under this agreement may proceed uninterruptedly from this date.
>
> Eighth. The party of the second part shall take, use, provide and make all proper, necessary and sufficient precautions, safeguards and protections against the occurring or happening of any accidents, injuries, damages, or hurt to any person or property during the progress of the erection of the work herein contracted for, and indemnify and save harmless the said party of the first part from the payment of all sums of money by reason of all or any such accidents, injuries, damages or hurt that may happen or occur upon or about said work, and from all fines, penalties and loss incurred for or by reason of the violation of any city or borough ordinance or harbor regulations, or laws of the Dominion of Canada or Province of Quebec, for which they are responsible, while the said work is in progress of construction.
>
> Twelfth. The party of the second part shall restore at his own cost all or any part of the work that may be damaged or destroyed before its acceptance by the aforesaid parties notwithstanding that payments on account of progress estimates may have been made previous to the occurrence of such damages.

The modifying letter, attached by the Phoenix Bridge Co. to the contract, stated that its understanding was that the contract should not become operative until the guarantee Act was passed and until satisfactory arrangements were made for payment; and

> It is further to be understood that the time named in the Agreement for the completion of the work is one which we do not guarantee and it is based upon the work proceeding uninterruptedly from this date. The date named we will do our best to keep. We cannot accept any responsibility for damages of any kind which may result from any delay in the completion beyond the date fixed in Agreement.
>
> We agree, however, to complete the work under the terms of said Agreement by Dec. 31, 1908, and will pay to the Quebec Bridge Co., Ltd., $5,000 per month for each month thereafter that the work called for by the said Agreement is not completed.
>
> Should there be any stoppage of the work for a period of six months from any cause for which The Phoenix Bridge Co. is not responsible, except from strikes and floods, thereupon an estimate shall be made of the total expense incurred by the Phoenix Bridge Co. on account of said Agreement to date, and after deducting all payments made to date, the balance plus ten per cent. of said total expense shall be immediately due and paid to The Phoenix Bridge Co. in cash by the Quebec Bridge Co., Ltd.
>
> We agree to modify the prices named in this Agreement, to the extent of any variation in the base price of plain metal on cars Philadelphia, from 1.80 cts. per pound and which variation may occur between this date and August 15, 1903. * * *

On Feb. 22, 1904, the Quebec Bridge & Railway Co. made the desired assurances of payment and called attention to its change of name. Mr. Reeves accepted these assurances March 15, 1904. The Commission's report says:

> There are no subsequent alterations of these business arrangements.

Thus it appears that the contract of June 19, 1903, solely, governs the subsequent work, except possibly as the letter of Mr. Reeves may be effective in modifying it. The Government, says the report, did not intervene in the contract, and assumed or exercised no authority over the Phoenix Bridge Co. Its checking and inspection were as against the Quebec Bridge & Railway Co. only.

The fact that the development of the Quebec Bridge work was so much delayed by the difficulties of financing the project, leads the Commission to examine [Appendix 5] whether any financial limitations exercised a detrimental influence on the design. It decides in the negative. The main question was as to Mr. Cooper's increase of the unit-stresses:

> He unquestionably increased the unit-stresses, but not to a point beyond those already adopted by the Bridge Department of the City of New York for its great bridges, and the increases can be stated to be in harmony with the most advanced practice of that time and due more to an instinct of wise investment than to any endeavor to simply cheapen the structure. * * *
>
> The facts * * * show that while there is no evidence of any cheap and insufficient work being purposely done by either Mr. Cooper or the Phoenix Bridge Co. there is evidence to prove that the financial weakness of the Quebec Bridge Co. seriously interfered with the carrying out of the undertaking.
>
> The Phoenix Bridge Company were limited only by the specifications as amended by Mr. Cooper, endorsed by the Government and concurred in by themselves, and no sum of money or total weight was set as a limit in the designing or building of the superstructure, the sole aim of all being to produce a safe and economical bridge.
>
> The Phoenix Bridge Company were paid for the work at so much per pound so there was no incentive to the Phoenix Bridge Company to make the bridge lighter than they deemed it should be.

A serious error is found by the Commission in one fact [App. 5 and 8] caused by the rush of work in the drafting-room of the Phoenix Bridge Co., following the contract of June, 1903. This error is chargeable to the financial limitations only in the sense that these made the progress of designing very jerky, and caused it to practically stop between 1900 and 1903, so that when the press of active work came there was no time to make new calculations.

The error in question is as follows: When the stress sheets for the 1,800-ft. span were prepared, the weight of the structure was assumed less than it later proved to be. The exact dead-load stresses were not recalculated before the designing was completed, and the designs therefore do not provide sufficient metal to bring the stresses within the specified limits. The weights as assumed and as actually found, in pounds, and the percentages of excess of the latter, are:

	Assumed for stress sheet	Actual, 6-25-07	Per cent, Excess
Half Suspended Span..	4,842,000	5,694,000	17.5
Cantilever Arm	13,205,200	15,804,000	19.6
Anchor Arm	13,317,600	17,318,000	30.0
Half Total.....	31,364,800	38,816,000	23.8

Of the total weight, 35,316,000 lbs. represents steelwork. A later calculation, Sept. 25, 1907, makes this figure 36,656,252 lbs. from the drawings, and the shipping weights totaled 37,039,941 lbs. This would make the total weight of the half bridge about 40,540,000 lbs., an excess of 29.2% over the assumed weight.

Mr. Cooper did not become aware of the error until he received Mr. Edwards' report on material of Feb. 1, 1906. At this time practically the anchor arm, tower and two panels of the cantilever arm [of the south half—Ed.] were in place. Realizing that there was no remedy and believing that the increased stresses were still within the limit of safety, Mr. Cooper permitted the work to proceed. He estimated that the increase in unit strains due to this error was from 7 to 10%.

The Working Organizations and Staffs.
(Appendix 7.)

The qualifications and the mutual relations of the men who were directly engaged in the engineering work of the bridge are judicially reviewed in App. 7. Of this review we give a rather full abstract, on account of the specific charge made in the Commission's findings that no engineer of experience was at the bridge site to direct the work in authoritative manner. It is stated in App. 10 that all parties concerned looked to Mr. Cooper, in New York, for the exercise of all authority in technical matters, and it is clear from the narrative of events leading to the collapse that this long-distance direction was fatally defective.

. . The Quebec Bridge & Railway Company maintained in its service and employed on the work a chief engineer, a consulting engineer, two erection inspectors and four mill and shop inspectors. The Chief Engineer, Mr. E. A. Hoare, M. Inst. C. E., had an extensive experience as a railway engineer, and had done most of the company's preliminary work. . . He had a high reputation for integrity, good judgment and devotion to duty. . . There is, however, nothing in Mr. Hoare's record that would indicate that he had the technical knowledge to direct the work in all of its branches.

The company's directors do not seem to have realized the importance of the duties pertaining to Mr. Hoare's position and . . while believing that he was not competent to control the work they still gave him the position, the powers and emoluments of the office of chief engineer.

While we can only consider this as a mistake on the part of the Quebec Bridge & Railway Company, yet we regret to say that such appointments are by no means uncommon and it must be recognized that in many cases, good executive ability is valued more highly or considered of more importance than special professional knowledge.

. . Mr. Theodore Cooper, of New York, was the consulting engineer. In the extent of his experience and in reputation for integrity, professional judgment and acumen Mr. Cooper had few equals on this continent and his appointment would have been generally approved. Mr. Cooper's strict duties were to examine, correct and approve the plans prepared by the contractors and to give engineering advice to Mr. Hoare when requested. Mr. Cooper and his chief assistant, Mr. Bernt Berger, carried on a most thorough and painstaking examination of the plans. Mr. Cooper appointed both shop and erection inspectors for reasons explained in his evidence, and had these inspectors report fully and regularly to him.

Mr. Cooper states that he greatly desired to build this bridge as his final work and he gave it careful attention. His professional standing was so high that his appointment left no further anxiety about the outcome in the minds of all most closely concerned. As the event proved, his connection with the work produced in general a false feeling of security. His approval of any plan was considered by every one to be final, and he has accepted absolute responsibility for the two great engineering changes that were made during the progress of the work—the lengthening of the main span and the

changes in the specification and the adopted unit stresses. In considering Mr. Cooper's part in this undertaking, it should be remembered that he was an elderly man, rapidly approaching seventy, and of such infirm health that he was only rarely permitted to leave New York.

Mr. Cooper assumed a position of great responsibility and agreed to accept an inadequate salary for his services. No provision was made by the Quebec Bridge Company for a staff to assist him nor is there any evidence to show that he asked for the appointment of such a staff. He endeavored to maintain the necessary assistants out of his own salary which was itself too small for his personal services and he did a great deal of detail work which could have been satisfactorily done by a junior. The result of this was that he had no time to investigate the soundness of the data and theories which were being used in the designing and consequently allowed fundamental errors to pass by him unchallenged. The detection and correction of these fundamental errors is a distinctive duty of the consulting engineer and we are compelled to recognize that in undertaking to do this work without sufficient staff or sufficient remuneration both he and his employers are to blame, but it lay with himself to demand that these matters be remedied.

During the construction of the substructure, Mr. Cooper visited the bridge site on several occasions, but did not visit the bridge during the erection of the superstructure. He visited the Phoenix Iron Company's shops but three times during the fabrication of the structure.

. . In the sense that the inspectors looked to Mr. Cooper for advice and directions almost entirely and that he appointed them and issued instructions to them, and also that he dealt directly with the contractors, he assumed many of the duties of a chief engineer; owing to the special nature of the work, he was the only one in the employment of the Quebec Bridge Company who was capable of assuming these duties. He was not authorized to act in this capacity, nor was he able to visit the bridge during its erection.

Norman R. McLure was an inspector assisting Mr. Edwards in the shops up to the beginning of erection, when he acted as inspector of erection, being employed during the winter as an inspector in the shops. He was appointed by Mr. Cooper with Mr. Hoare's concurrence. He was responsible to both Mr. Cooper and Mr. Hoare and received instructions from both, but reported to Mr. Hoare principally upon matters regarding monthly estimates, and to Mr. Cooper upon matters of construction. Mr. McLure had definite instructions in writing as to duties from Mr. Cooper (see evidence p. 80-81) but had none from Mr. Hoare. Mr. McLure is a technical man, a graduate of Princeton University (1904), and previous to the Quebec Bridge work was inspector of bridges for the New York, Ontario & Western Ry., and in so far as his experience fitted him, performed his duties well and is a painstaking and capable engineer. He had not full authority on the work and depended on Mr. Cooper for all technical advice and instructions.

. . Mr. E. R. Kinloch acted as inspector of workmanship throughout erection, having been appointed by Mr. Hoare and was responsible to him. Mr. Kinloch's experience on bridge work as given in his evidence shows that, while without technical training, he had been connected with the building of several heavy structures and was thoroughly capable of handling ordinary bridge erection. His duties were to watch the structure closely and to see that the erection work and particularly the riveting were properly done and in accordance with the instructions issued by the Phoenix Bridge Company. While the Phoenix Bridge Company did not recognize his authority, they cooperated cordially with him to the common end of endeavoring to obtain good work.

Mr. McLure and Mr. Kinloch worked independently, but all Mr. Kinloch's observations and criticisms were reported to Mr. McLure and these have added a great deal to the value of the records. Mr. Kinloch was thoroughly at home in his work and executed his duties carefully and intelligently. He appears from the evidence to have been a keen observer and fully impressed with the importance of his duties. We are, however, convinced that the bridge was too large for one man to thoroughly cover in detail all the work that was entrusted to Mr. Kinloch and that there should have been more inspectors of equal ability.

Mr. E. L. Edwards was chief inspector of shop work and was appointed by Mr. Cooper with the approval of Mr. Hoare. He reported to both Mr. Cooper and Mr. Hoare.

. . Mr. I. W. Meeser was Mr. Edward's assistant and his inspection was more particularly directed to the shopwork. . . The commissioners satisfied themselves during their visit to Phoenixville that both Mr. Edwards and Mr. Meeser thoroughly understood the work they had undertaken. The commissioners are not, however, satisfied that the shop inspection as arranged for by the Quebec Bridge & Railway Co. would have been as thorough as it was if it had not been aided throughout by the hearty cooperation of the officials of the Phoenix Bridge Co. and of the Phoenix Iron Co. The staff was too small; and it is our opinion that the Quebec Bridge Co. would have shown better judgment had it employed a larger staff under the direction of an independent man of wider technical knowledge and who would have been sufficiently forceful to hold his own against the contractors.

. . The officials of the Phoenix Bridge Co. most closely connected with the Quebec Bridge were the chief engineer, the designing engineer, the engineer in charge of details, the shop inspector, the superintendent of erection, the erection foreman, the resident engineer of surveys and the resident engineer on erection.

The chief engineer was Mr. Deans, who has occupied this position for many years and is widely and favorably known as an experienced bridge builder. Mr. Deans' personal duties are the general oversight of all work being executed by his company. He may be fairly described as its chief business manager. . .

The designing engineer was Mr. Szlapka, who had received a thorough technical education in Germany and has been with the Phoenix Bridge Co. for about 27 years, having held his present position for 21 years. . .

As usual in present bridge company organizations, Mr. Szlapka's work has been confined to his own department and his personal knowledge of the work of transportation and erection is limited. The evidence shows that Mr. Cooper, whose faculty of direct and unsparing criticism is well known, had every confidence in the ability of Mr. Szlapka and on previous works had had good opportunity to form his estimate of him. Mr. Szlapka was responsible for the entire work of designing and the commissioners are satisfied from their personal investigations at Phoenixville that this was conducted with care and energy. Mr. Szlapka's mistakes and errors, to which the disaster is directly attributed by the commissioners, are discussed elsewhere.

The engineer in charge of details was Mr. Charles Scheidl. Mr. Scheidl had received a technical education in Germany and has been with the Phoenix Bridge Co. for 24 years, during eighteen of which he has held his present position. His work in connection with the Quebec bridge, briefly stated, consisted of preparing the shop drawings from the general outlines of design that had been determined by Mr. Szlapka. The accuracy with which this work was done is proved by the records of the shop inspectors and of the erectors and was of the highest grade. Upon Mr. Scheidl was laid the burden of being personally responsible for the accuracy of every one of the shop drawings.

Mr. E. T. Morris was shop inspector for the Phoenix Bridge Co., his position being a permanent one. His duties were similar to those of Messrs. Edwards and Meeser and his employment practically provided for an additional inspection of the work in the shop. . .

An examination of the "field corrections" reported by the resident engineer of erection will show how thoroughly this shop inspection was done and by comparison of the records we find that the work of Mr. Morris was even more thorough and exact than that of Messrs. Edwards and Meeser. It is proper to credit the thoroughness with which this work was performed not solely to Mr. Morris but also to Messrs. W. N. Reeves, Deans and Norris, whose emphatic instructions concerning inspection he had received.

Mr. A. B. Milliken was superintendent of erection, having general jurisdiction over the handling of all the contracts of the company after the material was delivered to it by the Phoenix Iron Co. He has occupied his present position for about 17 years. . . His work throughout appears to have been thoroughly and carefully done. The system of erection was jointly designed by the engineering and erection departments of the Phoenix Bridge Co., the details of the members, their connections, the travelers and the general order of erection being determined by the engineers, and the equipment of plant and tackle by the erection department. Mr. Milliken appointed Mr. Yenser as foreman on the Quebec Bridge.

Mr. B. A. Yenser was Mr. Milliken's subordinate in charge of erection and was in absolute local authority. He had been a bridge erector for many years and had worked for the Phoenix Bridge Co. for about 15 years. . . It should be noted that Mr. Yenser had absolutely no authority to vary the program of erection which was arranged in Phoenixville and furnished to him in a book of instructions with accompanying plans. His position was largely an executive one, his duties being to carry out positive instructions and to see that the forces employed were worked to their full efficiency. He had orders to exercise extraordinary care in the inspection of the tackle and all handling appliances. Mr. Yenser had no technical training and his position did not call for it. His action in continuing erection on Aug. 28, 1907, was immediately referred to his engineering superiors and was approved. The evidence shows that he was an able and forceful superintendent, and that he went to his death with supreme confidence in the judgment of his superiors at Phoenixville.

Mr. A. H. Birks, the resident engineer of erection, who also perished in the disaster, had complete confidence in the ability and efficiency of the Phoenix Bridge Co.'s designers, whose abilities he had had ample opportunity to observe. . . He had received a thorough training in the design of the erection plant. His duties were to inspect the material as it arrived on the bridge for erection, to see that it was properly placed, and to watch the erectors to see that the program of erection as laid down in the Phoenixville written instructions was minutely followed. The evidence shows that these duties were performed with intelligence and fidelity. . .

In general it may be said that this staff was highly efficient, the men were well trained and had ample experience in the class of work that they were called upon to do and there is throughout evidence of great pride in their individual connection with the undertaking and of determination to do their utmost to make it a success in every way. The commissioners are of the opinion, however, that the Phoenix Bridge Co. erred in judgment and showed a failure to appreciate the magnitude and difficulties of the work that it had undertaken when it did not provide as part of this organization an engineer of erection who, by virtue of technical training and long experience on large bridge work, was fitted to take complete local control of the erection. In this they followed usual practice, which, however, was not applicable to this particular work.

Development of Specifications, General Design and Details.

[Appendices 6 and 8.]

The evolution of the specifications for the structure was completely traced out by the Commission, partly because of Mr. Cooper's strictures [see his testimony, Eng. News, Oct. 31, 1907] on the original specifications and because the specifications as a whole have been criticized unfavorably. A very brief statement, however, will cover the matter.

The specifications governing the cantilever designs of the competitive bids were put together by Mr. A. E. Hoare in 1898 largely from the 1896 general specifications of the Department of Railways and Canals. They were approved by the Department only on his representation that they were to be used only for the competitive bids and not for the construction of the bridge. However, they were embodied in the Government subsidy agreement of 1900. The construction of the approach span at either end of the bridge, 1901-'02, proceeded under revised specifications, on criticisms by the Department Engineer of Bridges, Mr. R. C. Douglas. But the original specifications came up again in connection with the main bridge, although Mr. Cooper had advised in 1899 that modifications be considered.

In 1903, when the main bridge was again actively considered, Mr. Cooper, in consultation with Mr. P. L. Szlapka, Designing Engineer for the Phoenix Bridge Co., drew up amendments to the original specifications. The resulting specifications of June, 1903, were criticized by Mr. Douglas, the government Bridge Engineer, but ultimately, by governmental Order-in-Council of Aug. 15, 1903, the whole matter of improving the specifications, etc., was left to Mr. Cooper,

> provided the efficiency of the structure be fully maintained up to that defined in the original specifications. . ; . . all detail parts . . to be . . as efficient for their particular function as the main members for theirs . . by the principles governing the best modern practice, and by the experience gained through actual test. . .

During the discussion which led to this Order, the government had proposed to employ a competent bridge engineer to examine and approve the detail plans for the structure, and this had actually been ordered. So emphatic were the protests against this course, on the part of Mr. Cooper, as well as the Phoenix and the Quebec companies, that the later Order was made which left the whole matter in Mr. Cooper's hands except that all plans had to be approved by the Department of Railways & Canals before their adoption.

Accordingly, Mr. Cooper fixed other loadings and other unit-stresses than the original specifications provided, and later from time to time made other modifications.

The manner and order of development of the detail plans for the structure may be understood very clearly from a perusal of the testimony of Mr. Szlapka and his assistant, Mr. Charles Scheidl [Eng. News, Nov. 28, 1907]. Briefly, Mr. Szlapka alone drew up the general design and computed the stresses, etc., while Mr. Scheidl, under his direction, elaborated all the details and directed and checked all working drawings. There was a great pressure upon the latter to turn out detail drawings, in 1903 to 1906, and this is largely responsible for the grave error,

already mentioned, of failing to calculate detail weights promptly and use them to recompute dead-load stresses.

Concerning the evolution of the general outline plans, a summary appears in the report:

The first preliminary plan of the Quebec Bridge was made by the Phoenix Bridge Co. for the Quebec Bridge Co. and is dated 30th November, 1897. A second plan was made 7th December, 1897, showing the lower chord curved. In response to our enquiry Mr. Szlapka states that the change from the straight to the curved lower chord was made for the sake of artistic appearance, either form being considered by him structurally satisfactory.

There are three other plans, dated 17th February, 1899, two of which show the lower chord of the anchor arm arched at both ends, and the other shows the anchor arm arched only at the main pier. In general outline this last plan was almost identical with that of the final design.

All of these five general, preliminary plans are drawn for a river span of 1,600 ft. The plan of Nov. 30, 1897, shows the cross-section of the river correctly, which indicates that information of this nature had been received from the Quebec Bridge Co. prior to that date.

The plan made by the Phoenix Bridge Co. and dated Dec. 7, 1897, is identical as to bridge outline, with the plan dated Jan. 13, 1898, and filed in the Department of Railways and Canals by the Quebec Bridge Co.

The plan which accompanied the tender of March 31, 1899, was one of the three plans dated Feb. 17, 1899.

Two more plans were made, dated April 22, 1900, both of which show the anchor arm with a lower chord in the shape of a complete arch, the main span on one being 1,723 ft. and on the other 1,800 ft. The contract for the bridge having been awarded on April 12, 1900, these plans were finished after the formal award was made; but the correspondence shows that the discussion of the lengthening of the main span had been going on for some time before April 12. Mr. Cooper's report recommending the 1800-ft. span is dated May 1, 1900. Another general plan, showing a bridge with practically the same outline as that used for the final design, was completed on May 6, 1900, and this, with slight modifications, was used in making a plan dated Oct. 6, 1900, and having the name of the Quebec Bridge Co. in place of that of the Phoenix Bridge Co. in the title. On April 14, 1901, the last preliminary general plan was made. All these preliminary plans were made by the Phoenix Bridge Co.

Material, Shopwork and Inspection.

[Appendix 9.]

On this subject we quote the larger part of App. 9 verbatim:

MATERIAL.—The steel supplied for the bridge was made to meet the requirements of the Hoare specifications with the exception that Mr. Cooper, finding that the tests on the full-sized eyebars were running a little low, called for the use of a slightly higher material for eyebar blanks.

The Hoare specifications called for an ordinary grade of structural steel very similar to the regular output of the mills. The testing requirements were not onerous but were in accordance with current practice.

The behavior of the metal, as evidenced by the wreck, was so good that the Commission was convinced that the disaster could not be traced to the furnaces or rolling mills. Its examination of these was accordingly rather general in character.

The following amounts of metal were supplied by the different mills:

Phoenix Iron Co., shapes	16,575,888 lbs.
Central Iron & Steel Co., eyebar blanks	14,827,400 "
Central Iron & Steel Co., plates	27,240,100 "
Carnegie Steel Co., plates	13,822,000 "
Bethlehem Steel Co., pins	993,600 "

. . . An examination of these records [of the mill tests.—Ed.], there being in the neighborhood of 5,000 tests in all, shows that there was nothing abnormal about any of the material and that it satisfactorily met the requirements of the specifications.

Full-sized tests of some 70 eyebars were also made in the large machine at Phoenixville in accordance with the requirements of the specifications. A number of the bars tested did not quite come up to specifications. The results of these tests were referred to Mr. Cooper who agreed to accept a certain number of weak bars, but raised the rolling mill specification so that there would be no further difficulty of this nature. These full-sized tests were made on finished eyebars, prepared in all respects as were the eyebars that were used in the bridge.

SHOP-WORK— . . . The evidence shows that Mr. Reeves and Mr. Norris fully appreciated the difficulty of manufacturing the large and complicated pieces of the Quebec Bridge and that the various superintendents and foremen were warned to give more than usual attention to the execution of the work. As a preliminary a full-sized wooden model of one of the panel points of the lower chords of the anchor arm was made and remained set up for the inspection of the shopmen. All details, such as the heads of rivets, etc., were shown on this model so that the shop men could realize the mechanical accuracy that was necessary in order that the several members meeting at a point would go together in the field.

. . It was the obvious intention of the Iron Company to do a first-class piece of work and it is in evidence that the management impressed not only on its own officials but also upon the employees of the Quebec Bridge & Railway Co. its desire that the shop inspections should be thorough and rigorous.

All pieces were inspected twice, once by the regular shop inspector employed by the Phoenix Bridge Co. and again by the inspectors for the Quebec Bridge & Railway Co. In the more delicate work the inspectors had orders not only to test the finished pieces but also to test the setting in the machines before the final cuts were made.

. . It was the practice of the shop to make the duplicate pieces for the north and south halves of the bridge at the same time; so that the bridge material now lying in Belair yard was manufactured under exactly the same conditions as that which was erected from the south shore. The Commission spent some time examining the material in Belair yard for the purpose of satisfying itself concerning the finish of the workmanship on the lower chords. This was found to be by no means perfect but the errors measured were of small amount. The shops were defective in that they lacked a well founded floor for the assembling of the heavy pieces. The methods adopted were also defective in that adjoining compression members were not fitted together before shipment. Some of the minor but by no means negligible errors discovered in Belair yard would have been detected by this fitting and it is a customary practice on heavy work. That errors similar to those observed at Belair existed on the south half of the bridge there can be no doubt, and Mr. Kinloch [Mr. Hoare's inspector of workmanship at the bridge.—Ed.] states that such errors were observed by him. That these minor errors at the joints contributed in some degree to the final disaster is probable, but our criticism in this case is not of the shopwork, which was of a fair grade. The fault lies in a design which called for an accuracy beyond the working of good shop practice.

The errors now being discussed are differences of length of the several ribs making up one chord and irregularities of surface at the field joints of the lower chords. The chord faces are found to be slightly dished and not true. It is not possible to determine by analysis the result of these slight errors, the larger of which would not exceed $^3/_{64}$-in. in dimensions.

The inspectors were instructed to work to the nearest $^1/_{64}$-in., but such accuracy is hardly practicable. We do not consider that such high accuracy can be maintained, at least not without fitting together adjoining pieces in the shop.

It is probable that some portion of the errors noted at Belair was due to the unavoidable racking of the members while in transport.

. . On the whole we consider that the inspection of the material and the work both in the mills and shops was reasonably efficient and that the collapse of the bridge is not attributable to want of care in either.

. . The lines of the several ribs in the chords are known to have been wavy to the extent of from ½-in. to ¾-in., but errors of this size and kind do not appear to have been considered a cause of anxiety. The existence of these wavy bends had been noticed by the shop inspectors and had been reported both to Mr. Szlapka and to Mr. Cooper.

We find no evidence to show that the seriousness of such minor errors in the compression chords and posts was appreciated by the engineers or was ever impressed by them upon the inspectors. The necessity of detail accuracy in compression members is referred to in Appendix No. 16.

The Problems of Transportation and Erection.

[Appendix 10.]

In App. 10, the report summarizes its opinion of the way in which the contractor dealt with the problems of transporting the enormous members of the Quebec Bridge from the shops at Phoenixville, Pa., to the site, and the problems involved in erecting the great structure. The opinion is very favorable on both matters.

TRANSPORTATION.—Although, as already noted, some members for the north half, lying at the storage yards near the bridge, show imperfections which were probably caused by racking in transport, yet this is not chargeable to lack of care in arranging for the carriage but rather to the design of these members being such as to make the injury unavoidable.

Many of the members were of a size and weight which taxed the facilities of the railways. Indeed, the capacity limits of the railways determined the maximum clearance dimensions and weight of the single pieces, and thus affected the detailing profoundly.

For some of the members special cars were provided so equipped as to make safe transportation a reasonable certainty. It may be noted that one member of the north half of the bridge has been lying in the Phoenixville yard for about three years awaiting the renewal of certain railroad bridges over which it would have to pass to reach Belair yard.

. . . The facilities for loading, unloading and transporting the material were entirely satisfactory so far as the safe delivery of the members was concerned.

ERECTION.—This problem had received very detailed study at Phoenixville, and this resulted in the formulation of a highly systematized program for the field-work. The field [illegible] was most of it new, built specially [illegible] this bridge. The hoisting and holding [illegible] had severe duty. Some of the members weighed 100 tons, and one lift of two [illegible] eyebars was 145 tons. No difficulties [illegible] the hoisting and handling work, however. The large traveler, which erected most of the [illegible] was the largest traveler ever built; it [illegible] about 1,100 tons when fully equipped.

. . . Great attention was given to the [illegible] equipment of this traveler and it performed its [illegible] in a manner entirely satisfactory to the erectors. [illegible] dence the erection workmen stated that they [illegible] worked on a bridge on which better appliances [illegible] vided, or on which the erection program had [illegible] perfectly arranged. In order to hasten the erection of the bridge, which had been delayed by lack of [illegible] connections, it was decided in January, 1906, to [illegible] suspended span with a small [top-chord.—Ed.] traveler so that the big traveler might be removed to the north shore at an earlier date. This program, which was followed, was found quite satisfactory and it tended to increase the safety of the structure during erection, as erection stresses were thereby reduced.

There was another side to the erection question, however, which gave more trouble. This was the matter of duly providing for the motions at the joints which would occur as the structure grew and the stresses in the several members increased. Every part of the structure was bound to take part in the progressive distortion, and the tendency for motion to take place at the joints [or else bending stresses to be set up in the members themselves] occurred in every portion.

The members most vitally affected by this phenomenon were the bottom chords of the anchor and cantilever arms, which consisted of compression members exclusively.

The joints between successive sections of bottom chord were detailed as butt joints, whose efficiency in transmitting the compressive stress would depend upon square and even seating, as these joints could be provided with only weak splice plates. Therefore it was necessary to face off the ends of the chords at such angles that they would come into full bearing under the full dead load, i. e., when the bridge was completed, which means that, when first erected, the joints could not be in full bearing, but would bear at an edge only [generally the upper edge]. The joints could not be riveted, of course, until they came to full bearing, and in the meantime their condition was somewhat precarious.

This matter is stated in clear language in App. 10 as follows:

In the design of the bridge a normal configuration and loading was assumed in which the stresses in all the members were intended to be axial. In other words, under these conditions no bending stresses would exist at the various joints; under any other loading, therefore, angular changes would either take place or tend to take place at the joints; that is to say, bending stresses would exist.

The shop lengths of all members being computed so that, in the normal configuration, the members had the normal lengths, it resulted that during erection, when the members were under little or no stress, the whole configuration was distorted, as compared with the normal configuration. The falsework upon which the anchor arm was built had therefore to be arranged to conform to the initial configuration. After the anchor arm was erected, the building of the cantilever arm gradually introduced and increased the stresses in the various members of the anchor arm and at a certain stage the anchor arm became free from the camber blocks on the falsework, which were lowered to assist this movement.

In the original distorted form all field butt joints were in contact only at one edge, since in the normal form they would be in full contact. With the increasing loads on the cantilever arm, due to the progress of erection, these joints gradually approached the condition of full contact and in doing so revolved about the edges in contact; in the meantime the splices were secured by bolts which could be changed as the movement at the joints improved the matching of the holes. The instructions issued by the Phoenix Bridge Co. were that when the joints finally closed, the splices should be permanently riveted.

It must be apparent that during the movement in question the stresses at these joints were applied first only at the edges in contact, and that it was not until the joints were fully closed that there was any possibility of uniform distribution of stress. Indeed this condition was not possible until the bridge would be completed and carrying its normal load, and the attainment of this condition would even then be dependent on the accuracy of the mechanical work at the joints.

These movements were regularly and carefully observed by the Phoenix Bridge Co.'s engineer in charge of survey work, and Mr. Deans states that these observations agreed closely with the expected movements as calculated by the designing engineers.

The adopted scheme of erection was carefully worked out in all details before the work of erection began. The results of this study were embodied in a book of field instructions, copies of which were furnished to the principal foremen on the work and to the representatives of the Quebec Bridge Co. These instructions were imperative and were not departed from or varied without approval of the Phoenix Bridge Co. at Phoenixville.

Mr. Kinloch, in his evidence, referring to these instruc-

tions, said: "In fact you had only to follow instructions and the thing would get there itself if you followed the lines laid down." This statement coming from a bridge erector of Mr. Kinloch's experience is a tribute to the completeness of the pre-arranged system of erection.

There can be no doubt that the camber problem in the Quebec Bridge was much more difficult than in ordinary structures on account of the magnitude of the bridge and the great size of its members.

But as will appear from the following matter, April 11, the movements in question did not take place quite in the expected manner, at least in the anchor arm, and there is a suggestion that the discrepancy had some relation to the subsequent failure of the bottom chord of the anchor arm. The last sentence of the quotation just above is, indeed, a very mild statement. Unquestionably a great courage was needed to face the task of maintaining so large a structure in proper condition while its most essential joints were in a temporary and imperfect state.

Progress of the Erection, Difficulties that Arose, and the Events Prior to the Collapse.

[Appendix 11.]

The real story of the collapse of the bridge is clearly written in the history of occurrences during the erection. The Commission's report contains a remarkably interesting summary of this history in App. 11, and we reprint this substantially in full. The prior story of the preparation of designs, the long-delayed taking in hand of the enterprise, the preparation of detail drawings under great pressure of time, and, as recounted in Mr. Szlapka's testimony [Eng. News, Nov. 28, 1907, p. 584, col. 3], the question raised at one time as to the strength of the bottom-chord latticing, form merely the setting for the story of what actually happened when the structure was being built.

GENERAL PROGRESS OF ERECTION.—The contract of June 19, 1903, went into effect on March 15, 1904, and field work started promptly. By September, 1904, the erection of steel falsework for the south anchor arm was well under way, and the large traveler and its supports were being built. Lack of rail connection from the Chaudière storage yard to the south end of the bridge delayed the work somewhat until the middle of July, 1905. By that time the falsework and traveler were complete and erection of the steelwork began. Two months sufficed for the setting of bottom chords and main pier shoes and pedestals. By the end of the season six panels [of ten] of the anchor arm were in place, about 10,500,000 lbs. of permanent metal having been erected this season.

In 1906, work began April 16, and by the end of June the anchor arm was complete. As its top chord consists of eyebars, this arm cannot support itself as a "simple" truss, and had to rest on falsework until the cantilever arm had been built out far enough to lift the anchor arm off its supports, at which time the top chord would be permanently in tension. The entire cantilever arm of the south half was erected by the end of November, 1906, and the anchor arm was then wholly free from its falsework. But the course of its lifting off was irregular, as will be described. The metal erected in 1906 amounted to 21,000,000 lbs.

In 1907, much field riveting was done in the early weeks, and erection was taken up in June. The large traveler was used to place the connecting links between cantilever arm and suspended span, and to erect the small traveler running on the top chord of the trusses. The erection of the suspended span was begun on July 13 with the small traveler, and the dismantling and removal of the large traveler then proceeded. Both operations were still in progress on the day of the collapse, August 29. Less than 3,000,000 lbs. of metal were erected in 1907; the August progress estimate showed total metal erected as 34,400,000 lbs. Work had also been started on the north shore during this season, the falsework for the anchor arm (brought over from the south shore) being erected at a leisurely rate. No rail connection was yet available between the north end of the bridge site and the Belair yard, located near the junction of the Canadian Pacific and the National Transcontinental Rys., and this promised to delay erection of the north half.

The work done in 1905 proceeded satisfactorily to both parties, with a few minor difficulties. The same is to be said of the 1906 work, but here the irregular lifting of the anchor arm from the falsework gave some concern and led to some controversy. In 1907 more serious troubles arose.

DIFFICULTIES AND ACCIDENTS IN 1905.

CHORD A 9-L.—In April, 1905, this chord had a severe fall while being handled in the Chaudière yard. One of the hooks that were being used in raising it broke, and the whole chord fell, one end striking on a yard plate lying on the ground, and the other on a pile of eyebars. The drop was 5 ft. at one end and about 3 ft. at the other. The chord struck in such a way that any resulting bend would have been at right angles to the deflections measured on Aug. 27, 1907. Two lower flange angles were broken. This chord was repaired in July, 1905, in accordance with drawings received from Phoenixville, and to the satisfaction of the Quebec Bridge Co. We have examined these repairs since the fall of the bridge, and we find nothing to justify us in connecting them with the disaster. Whether the chord was strained by its fall so that it afterwards bent more readily under stress is a matter of conjecture that cannot be settled. . .

PAINTING.—There was some discussion because the designs were such that water and snow could lodge in many pockets of the steel work and that other parts of it were inaccessible for future painting. Mr. Hoare considered that this was an "oversight" on the part of both of the Phoenix Bridge Co. and Mr. Cooper, and on Mr. Kinloch's advice insisted on its being remedied. No changes were made, but better provision for painting was arranged for in the members not yet built.

MASONRY.—It was found necessary to delay the placing of the pedestals until the surface of the masonry upon which they were to rest was dressed level. Mr. Cooper would not permit the use of a lead plate under the pedestal and had pieces of duck, heavily coated with red lead, used instead.

MAIN SHOE, RIGHT TRUSS.—On placing this in position it was found that the bottom did not bear evenly on the pedestals, there being an opening parallel to the bridge center line about 4 ft. wide and perhaps $^{3}/_{16}$-in. high at the maximum. It was decided that this would close as the weight on the shoe increased, but this closing had only partially occurred up to Aug. 29, 1907. The shop inspector (Mr. McLure in this case) states that no warp existed in the finished pieces in the shop, and that it must have been caused by handling and transportation. The matter does not call for further comment.

LOWER CHORDS; BENDS.—It was noticed by Mr. Kinloch that lower chords A 1-R, A 2-R, A 3-R,* after they were set, and before any stress came on them, did not look straight, but were wavy to the extent of perhaps ½-in. He discussed this matter with Messrs. Birks and McLure and it was decided that it was of no importance. It was also noted early in September, 1905, that the openings at the lower chord splices did not correspond exactly with the erection diagrams "but seemed to average up about the same," and also that the inside ribs of chords at splices 1 and 2 did not line up well.

DIFFICULTIES AND ACCIDENTS IN 1906.

TOP OF CENTER POST.—On June 2 Mr. McLure reported to Mr. Cooper that the bearing surfaces at the top of C P 1 both R and L were not even and would not give a good bearing to the center post caps, these surfaces being made up of the tops of the posts themselves and of two brackets attached to each. Mr. Cooper immediately wired Mr. Hoare as follows: "Do not allow posts C P 1 erected until top is made level. Notify McLure." Mr. Hoare immediately issued instructions to this effect. The Phoenix Bridge Co. sent Mr. Scheidl to check Mr. McLure's measurements and the defect was finally made good in accordance with Mr. Cooper's detail instructions to Mr. McLure. The fault lay both in the fitting of the brackets and in the facing of the posts by the planer. Mr. Cooper considered such workmanship to be disgraceful; but the defects as stated to him were rather exaggerated owing to the methods of measurement adopted by the inspectors.

COMPRESSION MEMBERS.—On July 20 Mr. McLure wrote to Mr. Edwards as follows.

> On a number of the compression members that we have erected—particularly on three or four anchor arm bottom chord sections, in chord 621 8-L (south cantilever arm, bottom chord) and in main diagonal sections for both anchor and cantilever arms (T 5 and T 50) and on 621 S P-5 sections (south cantilever arm sub-posts) especially the latter—in sighting from end to end, the webs in places are decidedly crooked, and show up in wavy lines apparently held that way by the lacing angles. This makes a very bad appearance, for a person seeing a member like that, and knowing it to be in compression, would at once infer that it had been over-strained sufficiently to bulge the webs. As to its actual effect in the number of cases I have figured out there is no possibility of this causing trouble, as long as the lacing in the members in question is intact.

On Sept. 22 Mr. McLure reported to Mr. Cooper a deflection of ½-in. in a distance of 36 ft. and of ¼-in. in a distance of 17 ft. in the upper section of post 3-L, cantilever arm (621 U P 3-L). Mr. Cooper replied that he did not like the distortions but did not see that anything could be done at that stage. No effort was made to correct any of these irregularities, all of which were due either to shop errors or to racking in transportation. We do not connect these undoubted faults immediately with the disaster.

REMOVAL OF STEEL FALSEWORK.—In August, 1906, the Phoenix Bridge Co. issued instructions covering the removal of the steel falsework bents, under members T O and P 1, anchor arm. The draft of the instructions showed that the Phoenix Bridge Co. expected the portions of the anchor arm near the main pier to lift first, as the weight erected on the cantilever arm increased, but desired, for convenience of erection on the north shore, to take down the bents near the anchor pier as soon as possible. On Sept. 15 Mr. McLure reported these instructions in detail to Mr. Cooper, and asked him for directions concerning the matter; he also reported that no lifting was yet visible at any point in the anchor arm. On Sept. 17 Mr. Cooper directed Mr. McLure to permit the removal of the falsework, provided he was satisfied that the remaining bents would not be overloaded. On Sept. 29 Mr. McLure reported that E P-R had lifted clear of the falsework and on the same day it was noticed that T O O O-R was free. After discussion in the "field," the blocking under T 5-Z, both R and L, was lowered ⅝-in., T 5 Z-R then swinging free. On Oct. 2 Mr. Cooper advised Mr. McLure that he thought the intermediate bents were too high and that he should examine them for evidence of extra loading and have them slacked down. "The whole must be rather a matter of careful observation and judgment rather than any reference to theoretical lines." Mr. Cooper read this letter to Mr. Szlapka and during the following week the blocking under T 5 Z, P-4 and T O O O O was lowered on orders from Phoenixville. As this was done without notice to Mr. McLure, who had received Mr. Cooper's instructions about the falsework, he immediately protested against this failure to recognize the inspectors of the Quebec Bridge Co. A short and rather sharp controversy arose over this, which was closed on Oct. 20 by a personal letter from Mr. Hoare to Mr. Deans, in which Mr. Hoare very definitely asserts the importance of Mr. McLure's position as a representative of Mr. Cooper and himself and makes it clear that no important steps are to be taken in the future without Mr. McLure's knowledge. * * * * In the week ending Oct. 29, T 5 Z, P 4, T O, and E P, were reported as free from the falsework and in the following week the blocking at T O O, P 2, T O O O and P 3 was lowered, P 1 swinging clear while this was being done. By Nov. 3, only T O O and P 2 [third and fourth panel-points—Ed.] were still bearing and by further lowering of the blocking, the whole truss was set free before Nov. 28. This record shows clearly that the right truss rose more quickly than the left truss, and that the center of the anchor arm remained resting upon the falsework for the longest time.

In his evidence Mr. Cooper has expressed the opinion that the blocking near the center was left too high, and that it acted as a fulcrum, permitting E P [the end post] and T O [the first sub-vertical] to lift from the falsework at an early date, whereas, theoretically, they should have been the last to lift. He suggests that this condition may have produced an undue and unprovided-for strain on the anchor arm splices.

There is no evidence that any serious action of this nature took place, Mr. McLure having been unable to observe any signs of stress at the suspected points, and no deformations in a vertical plane being anywhere on record. In our opinion the failure of the Phoenix Bridge Co. to more closely adjust the blocking of the truss to its movements was an error of judgment, as the stresses produced by the gradual working of the truss are not calculable and the movement should be made as free as possible.

MR. COOPER'S POSITION.—The Commission has been unable to satisfactorily determine the respective duties of Mr. Hoare and Mr. Cooper, their real positions being perhaps better brought out by the events of 1906 than by any other evidence. According to Mr. Deans, Mr. Cooper had to approve all plans, but all other authority was vested in Mr. Hoare, and this opinion Mr. Deans continued to hold throughout the work. According to Mr. Parent, Mr. Hoare was practically an executive officer acting in all technical matters on the direction of Mr. Cooper, who was, de facto, Chief Engineer. Mr. Cooper himself has stated that the erection plans were not subject to his authority, and has disclaimed any responsible connection with the inspection either in the shop or in the field. With few exceptions, all his directions are advisory and not imperative, and he seems to have endeavored throughout to avoid encroaching upon the privileges and rights properly pertaining to Mr. Hoare's position. He gave frequent directions to both Mr. McLure and Mr. Edwards on technical matters, but

*An explanation of the system of marking will be found in our article of Sept. 5, 1907. The numbering of the anchor arm started from the anchorage, that of the cantilever arm from its outer end. The lower chord members have no distinguishing letter but only a number. The prefix A denotes anchor arm.—Ed.

throughout the construction period (August, 1905, to August, 1907) he had practically no correspondence with Mr. Hoare. Mr. Cooper's opinions, when given, were accepted by the inspectors as instructions. The impression left with us is that throughout the work Mr. Cooper was in a position of a man forced in the interests of the work to take responsibility which did not fully belong to his position, and which he was not authorized to take, and that he avoided the assumption of authority whenever possible.

Such an organization cannot from an executive standpoint be considered entirely satisfactory.

DIFFICULTIES AND ACCIDENTS IN 1907.

RIVETING.—It had been intended to delay much of the riveting of the structure until the erection of the south half of the bridge was completed, and all joints had their full stress; but at a meeting between Mr. Cooper and Mr. Szlapka on May 10, 1907, it was decided that riveting could be done at once at all joints where the connecting pieces had taken their full bearing. The estimate of the amount of field riveting in the south half of the bridge was as follows:

Part of bridge.	No. of rivets.
Anchor arm and center posts	121,000
Cantilever arm	98,700
South half of suspended span	53,300
Total	273,000

Some minor riveting was done in 1905, and in 1906 the joints of the floorbeams and those near the anchor pier were riveted, but the bulk of the riveting was not started until 1907.

On Aug. 3 Mr. McLure reported that the anchor arm was 90% riveted, although the bottom lateral braces in panels 6, 9 and 10 were not riveted; and that 40% of the riveting on the cantilever arm was done. At the same date the lower chord splices at 5-6, 9-10 and 10-11 were the only chord splices in the anchor arm remaining unriveted. Throughout the season the work proceeded satisfactorily; there were practically no difficulties until after Aug. 1.

TROUBLE AT BOTTOM CHORD JOINTS.—The difficulties with the lower chords that finally resulted in a collapse of the bridge were noted early in the season, but those first observed were considered to be of minor importance. The joints between lower chords 5 and 6, anchor arm, remained open 1/16-in. on the lower side, long after all the others had closed. They finally closed shortly before the disaster and on Aug. 29 were being riveted. No explanation has been offered of the slow closing of these joints and from their nearness to the falsework bents at T O O and P 2 it is possible that the pressure of the falsework may have had something to do with this.

On June 15 Mr. McLure reported to Mr. Cooper as follows:

> In riveting the bottom chord splices of south anchor arm, we have had some trouble on account of the faced ends of the two middle ribs not matching as per following sketch (the sketch shows that at the lower sides the middle ribs of the abutting chords were out of line by 1/4-in. to 1/4-in., this offset decreasing to nothing near the mid-depth of the ribs). This has occurred in four instances so far and by using two 75-ton jacks we have been able to partly straighten out these splices but not altogether. These were probably in this condition when erected, but owing to the presence of the bottom cover plate, it was then impossible to detect them, and it was only when this plate was removed for riveting that the inequality was noticed. The chords found in this shape were between 3 and 4, 7 and 8, and 8 and 9 in east truss, and 8 and 9 in west truss. You will note that this occurs only on inside ribs, which are provided with but a single thin splice plate each. I think that a heavy plate on each side of these ribs, bolted up tight when chords were erected, would have remedied this, i. e., drawn the ribs together till the "faced ends matched."

Mr. Cooper replied on June 17, saying:

> Make as good work of it as you can. It is not serious. It would be well to draw attention to as much care as possible in future work to get the best results in matching all the members before the full strains are brought upon them.

It should be noted that of the four joints mentioned, those between chords 3 and 4 and 7 and 8 had originally been opened at the lower side and had come together by "camber" movement; but the 8 and 9 joints had been set with the lower edges abutting. During the first stages of erection, the upper edges of all the ribs at a joint were exposed to view, as the upper cover plate was not in place. Mr. Kinloch, to whose practical knowledge of bridge work and powers of observation much of the excellence of Mr. McLure's reports is due, states in his evidence that he observed gaps between abutting ribs as great as 1/32 in. due to irregular finish of the planed ends of the chords. In the examination of the material in Belair yard the Commissioners found irregularities of workmanship which would account for the conditions described above, and in our judgment these could have been avoided only by matching the chords together in the shop previous to shipment. The small gaps between abutting ends of chords closed as the pressure on the chords increased, with no result other than producing irregularity of stress, but the lateral deviations had to be corrected by the use of jacks.

As Mr. Cooper in his evidence has expressed the opinion that these lower chord joints were, during erection, the weakest and most hazardous part of the structure, and that they suffered from lack of appreciation of the necessary care to be given them, it is advisable to closely review all evidence concerning them.

The chords consisted of four deep and narrow ribs latticed together and finished with square ends so that the pressure might be transmitted from one chord to the next by contact of the abutting ends. Under the system of erection adopted it was possible to place the adjoining chord ends in contact only at either the upper or lower edges, and it was expected that the chords would gradually turn during the settlement of the bridge until the end surfaces came fully in contact, as has been more fully described in appendix No. 10. This expectation was realized. The adjoining chords were held together by eight splice plates, an upper and a lower horizontal plate, two vertical plates on each outside rib and one vertical plate on each inner rib. The order of erection required that the lower plate should be put in position before the next chord was set; the vertical plates were next placed, and the erection of the joint was finished by bolting on the upper plate. Owing to the erection angle at the joint, it was possible to use full size bolts on only one horizontal plate and one edge, either upper or lower, of each vertical plate. The instructions with regard to the bolts were very definite and read as follows:

> All bottom chords to have 2/3 of all holes of web splices filled with 1-in. bolting on the outer ribs, and 2/3-in. bolts on the inner ribs, or their equivalent in smaller bolts or drifts. For top splice plate apply rule 1 (this requires that every hole shall be filled with a bolt) and never take off splice plate again, not even while driving rivets in web splices. Bottom splice plate to be bolted with bolts (2/3 value). While driving rivets in web splices of chords, remove bottom splice plate and bolt across flanges temporary angles to keep flanges in place.

Owing to the camber openings at the joints it was found necessary in some cases to use 2/3-in. bolts, as no larger bolts could enter the holes in their erection condition.

The evidence shows that these instructions were carried out, but not with a full appreciation of their importance. * * * We are of the opinion that the top and bottom cover plates and the splice plates for the outside ribs, all of which could be readily seen by the inspectors, were correctly bolted, but there may have been some cases of insufficient bolting on the inside ribs. Such cases were, we think, rare.

It was intended that, as the camber openings closed, the smaller bolts should be taken out and replaced by larger bolts on all outside plates, the inner plates being difficult of access until the bottom chord plate was removed. This idea does not seem to have been followed in practice to any extent nor is there any evidence to show that the bolting was systematically tightened up as it worked loose with the adjustment of the structure. The evidence also shows that the bottom cover plates were left off during the whole period of riveting a joint, (usually from ten days to two weeks) and that in the case of 7-8-L cantilever arm this plate was off for nearly the whole month of August, 1907. We must therefore conclude that the splice plates at the joints were rather loosely attached and that the importance of rigidity at these points was strangely overlooked.

It should be noted that this system of bolted splices was a necessity due to the method of erection adopted, but that there was no reason why the end details of the chords and the splice plates themselves should not have been much more strongly and rigidly designed. The erection problem was unique in magnitude, particularly in the camber requirements, and the method followed by the Phoenix Bridge Co. closely corresponds to that in general and successful use on smaller structures. It is open to criticism on theoretical grounds and it is possible that other engineers might by other design serve the same ends; the problem in its dimensions is so entirely new, that there is room for much study and invention in erection methods for great structures.

We know of no reason why the method adopted cannot be successfully used, but the evidence shows that the Phoenix Bridge Co. failed to appreciate the important influence that end details and splices had on the strength of the chords. Steps were not taken to ensure that the work was so handled that the maximum rigidity consistent with design was secured at these joints. Considering the circumstances, we know of no good reason why the riveting should not have been much further advanced before the great stresses created by the erection of the suspended span were thrown upon the joints. The report of Mr. McLure on Nov. 10, 1906, shows that all but eight of the 40 lower chord joints were then closed and ready for riveting. Mr. Cooper has clearly stated that he did not consider that the erection methods were subject to his control, although the evidence shows that he was frequently consulted about them, both by Mr. Szlapka and by Mr. McLure. The erection problem in this case was of great importance, and the Quebec Bridge Co. did not place their interests under the direct and responsible control of an experienced engineer acting solely on its behalf.

MORE SERIOUS TROUBLE.—Difficulties developed almost as soon as the erection of the suspended span got well under way. On Aug. 6 Mr. McLure reports as follows:

McLure to Cooper, Aug. 6, 1907.

> Dear Sir: In riveting up the splice between 8 and 7 in the west truss of south cantilever we found the condition of the inside ribs at splice indicated in following sketch. Owing to the limited space between the two inside ribs, it would be impossible to jack this splice back, and as the condition is nearly as bad at the top of the splice, we have proposed a diaphragm between the two inside ribs to cover the first five rivets up from the bottom on each side of the splice, as indicated in red in the sketch above. The splice plates being riveted on the two inside ribs will be necessary to cut out and redrive 20 rivets to do this. This provision, together with the top and bottom cover plates, should be sufficient to hold this splice against the thrust due to its being out of line, which thrust when under its maximum compressive stress I estimate at not over 60,000 lbs.
>
> The Phoenixville office is being notified of this plan, and if they will approve will wire us. If this also meets with your approval or if you wish to suggest another way to remedy the difficulty, will you please wire me at St. Romuald, P. Q., c/o Phoenix Bridge Co., as the riveting gangs are ready to finish riveting this splice. (Signed) N. R. McLure.

Upon receipt of this letter, Mr. Cooper wired the Phoenix company as follows, Aug. 8:

Cooper to Phoenix Bridge Co., Aug. 8, 1907.

> Method proposed by Quebec for splicing joints of lower 7 and 8 chords is not satisfactory. How did bend occur in both chords? (Signed) Theodore Cooper.

and wrote Mr. McLure on Aug. 9, as follows:

Cooper to McLure, Aug. 9, 1907.

> Dear Sir: Yours of the 6th regarding bent condition of lower 7 and 8 chord joints came yesterday. I wired Phoenix that the proposed method as sketched by you for repairing was not satisfactory. Also asked what you should have reported, how did both these chords get bent?
>
> In my opinion these webs can be brought back to proper line by use of 15 to 20 1-in. bolts, threaded at both ends for nuts, passing through the two webs of that half of chord. Of course means must be taken to stiffen the straight web against its bending when the bolts are tightened.
>
> If necessary, after getting the bent webs in line, to hold them, spacers and possibly some through bolts may be used.
>
> Some more satisfactory method than the one shown in your sketch must be devised.
>
> Mr. Deans telegraphs that upon Mr. Szlapka's return he will give me fuller facts.
>
> (Signed) Theodore Cooper.

Then the following telegram was received from Mr. Deans:

Deans to Cooper, Aug. 9, 1907.

> Mr. Szlapka happened to be at bridge site yesterday—expect him home tomorrow—with full information concerning chord joint, will then write you fully.
> (Signed) Jno. Sterling Deans.

To which Mr. Cooper replied as follows:

Cooper to Deans, Aug. 9, 1907.

> Dear Sir: Your telegram regarding chord joint at hand, the method proposed as sketched by Mr. McLure is not satisfactory as I telegraphed yesterday.
>
> These bent webs can be pulled back by use of about 15 to 20 1-in. bolts (in 1 1/16-in. holes) threaded at both ends for nuts, passing from the outer to the inner bent web. The outer straight web being stayed in some manner against its bending.
>
> If the bent webs after being pulled into line, tend to go back when released from the bolts, stays must be introduced to hold them in position. Possibly it may be necessary to permanently rivet in some of these 1-in. bolts.
>
> Please let me know what method you propose to use.
>
> It is a mystery to me how both these webs happened to be bent at one point and why it was not discovered sooner. (Signed) Theodore Cooper.

On August 10, Mr. Deans wrote as follows:

Deans to Cooper, Aug. 10, 1907.

> Splice Cantilever Chords 7 and 8.
>
> Dear Sir: Mr. Szlapka did not return today as expected, but will no doubt be here on Monday, when we will write you at once.
> (Signed) Jno. Sterling Deans.

On 12th Mr. Deans wrote as follows:

Deans to Cooper, Aug. 12, 1907.

> Chord Splice South Cantilever Arm, 7-L and 8-L.
>
> Dear Sir: Mr. Szlapka reached the office this morning and I am able to give you information in connection with this one joint.
>
> All ribs of the chord 7-L have a complete and full bearing on ribs of 8-L. The bend was no doubt put in the rib in the shop, before facing and was probably done when pulling the ribs in line to make them agree with spacing of these ribs and the clearance between ribs, called for on the drawing. The bend being on only one rib of one chord, there being a full bearing over the entire rib, all splice plates being readily put in position, we do not think it necessary to put in the diaphragm, suggested by the erection department.
>
> Please let us hear from you on this subject promptly and oblige. (Signed) John Sterling Deans.

On Aug. 13, in reply to Mr. Deans, Mr. Cooper wrote as follows.

Cooper to Deans, Aug. 13, 1907.

> Dear Sir: The information regarding chord splice 7 and 8-L is so different from the dimension sketch sent by Mr. McLure, I can take no action on this matter till the exact facts are presented. Please have your resident engineer and Mr. McLure re-examine this joint and send the exact condition of this rib, as to the amount of the bends and relation of the bearing surfaces to each other.
>
> I don't see how one rib being bent, only, as stated in your letter, there can be a complete and full bearing of these ribs.

Neither can I understand how pulling the rib into line at the shop could bend it out of line.

I will write Mr. McLure today to have a further investigation of this joint and to report as promptly as possible.

(Signed) Theodore Cooper.

and on the same day Mr. Cooper wrote Mr. McLure:

Cooper to McLure, Aug. 13, 1907.

Dear Sir: Mr. Deans writes me that only one rib at joint 7 and 8-L is bent and still that there is a full and complete bearing, that the bend was no doubt put in the chord in the shop before facing.

I have asked him to instruct his resident engineer to join with you in making an exact report, with dimensions of the conditions of this joint, with amount of bearing and if it is a square bearing or a skew.

In reference to the splicing of T-5 and T-50 mentioned in your letter of the 10th, I do not care to interfere with the regular programme as I have not followed the various actions of the loadings at different stages. Without going into it carefully, I think there will be more compression at these points with more of the suspended span in place.

Please report promptly regarding joint 7 and 8-L with all the facts. (Signed) Theodore Cooper.

Mr. Deans wrote Mr. Cooper on 14th as follows:

Deans to Cooper, Aug. 14, 1907.

Dear Sir: Chord splice 7 and 8-L. Your letter Aug. 13.

I will have a full and complete report made of this joint by Mr. McLure and Mr. Birks and submit it to you earliest possible moment.

(Signed) John Sterling Deans.

On Aug. 14 Mr. Cooper received the following letter of 12th from Mr. McLure:

McLure to Cooper, Aug. 12, 1907.

Dear Sir: I beg to acknowledge the receipt of your letter of Aug. 9 and have noted what you say regarding the method of repairing splice between chord 7 and 8 cantilever arm west truss. We will not do anything with this then until the matter has been arranged between yourself and Mr. Szlapka.

The reason I did not report at first as to how these chords got bent was because there were many different theories here as to the cause, no one of which I was at that time ready to accept. One thing I am reasonably sure of, and that is that the bend has occurred since the chord has been under stress, and was not present when the chords were placed. This being the case, the cause of the bend would seem to be the slight overrunning in length of the bent rib in either chord 7 or 8. Owing to the fact that these chords are faced on the rotary machine (the four ribs at once) this would at first seem to be out of the question, but it seems to me that after the first end of a chord has been faced, in turning it with the crane, to bring the other end into position for facing, it might be possible for one rib to work slightly by the others longitudinally, without being noticed, and in spite of the latticing and thus cause a slight difference in length. In fact, in taking the opening in the chord splices on the south anchor arm, it has often been noticed that a considerable variation existed between the openings of the different ribs at the same splice, which difference I was not able to account for except by the above theory that, during transportation, and in the handling before erection, some of the ribs have worked slightly in a longitudinal direction by each other. In the case in question, of course, this must have happened between the time of facing one end and the other. If this is correct, then it will be a pretty hard matter to draw the splice back into line with bolts, and our idea in suggesting that diaphragm was to prevent this eccentricity from increasing, rather than to correct that already there.

As I had supposed, the strike in force for the last three days of last week, has been settled and work has again resumed this morning. A meeting of the "Union" was held Saturday night and enough of the discontented element had been lost so that when the matter was brought to a vote the majority were found to be in favor of returning to work under the original agreement. Those who were not in favor of returning to work, however, are now leaving so that our force is reduced greatly on both sides of the river.

Since writing the above I have discovered that splice between the chords 8 and 9 on west truss of south cantilever arm is in the same condition exactly as that between 7 and 8, except that the bend is only 5/16 in. instead of ¾ in. at the bottom, and runs out so that on top this rib is in line as are the other three.

This is the same rib, and the bend is in the same direction as that reported for the other splice. When it is decided in what way to treat the splice between chords 7 and 8 we will repair that between chords 8 and 9 in a similar manner. (Signed) N. R. McLure.

To this Mr. Cooper replied on Aug. 15 as follows:

Cooper to McLure, Aug. 15, 1907.

Dear Sir: None of the explanations for the bent chord stand the test of logic.

I have evolved another theory, which is a possible if not the probable one. These chords have been hit by those suspended beams used during the erection, while they were being put in place or taken down. Examine if you cannot find evidence of the blow and also make enquiries of the man in charge.

(Signed) Theodore Cooper.

A further report was made by Mr. McLure on Aug. 16:

McLure to Cooper, Aug. 16, 1907.

Dear Sir: Referring to your letter of 13th, regarding splice between 8-L and 7-L on south cantilever arm you have no doubt by this time received my letter of the 12th instant, giving my theory of the cause of this bend. These conditions are as indicated in my report of Aug. 6. Mr. Birks, the resident engineer, for the Phoenix Bridge Co., reported exactly the same thing in somewhat different language to Phoenixville, but Mr. Deans had evidently taken a different meaning from his report than was intended. He evidently thinks that only one rib of one chord is bent, whereas it is the same rib at each chord, as indicated in the sketch I sent you. There is really nothing to add to the two letters I have already written regarding this bend, except to say that all the four ribs have full bearing on each other, as indicated also in the sketch of Aug. 6. In order to verify our first reports, Mr. Birks and I made a careful and more thorough measurement of this splice today, both top and bottom, and I am enclosing a blue print of a sketch made as a result of these measurements. It indicates practically the same condition as described in my first letter, except that it is given more in detail.

As to the cause of this bend, regarding which I wrote you on Aug. 12th, Mr. Deans seems to think that it was put in in the shops; but that is because he did not understand the conditions existing. Aside from the fact that it would be hardly probable that these two ribs of different chord sections, should be bent the same way, exactly the same amount in the shops to dimensions ½-in. to ¾-in. less than called for, I am reasonably sure as I said before that this condition did not exist before the erection of these chords, as I have personally inspected every member yet erected in this bridge thus far, except the bottom chords of anchor arm, on the cars just before the erection, looking particularly for bends in ribs of compression members, and whenever discovered have taken measurements of the amounts and recorded them. If these ribs then had been this much out of line before erecting, it would be well nigh impossible to miss seeing them. Consequently the only way the bend could have occurred, it seems to me, is that reported in my letter of Aug. 12.

I trust that these explanations, with the enclosed sketch, will make the matter entirely clear. Mr. Birks is sending same sketch to Phoenixville today.

(Signed) N. R. McLure.

Mr. Deans also received a copy of this sketch and wrote Mr. Cooper on Aug. 20 as follows.

Deans to Cooper, Aug. 20, 1907.

Dear Sir: We have advice from your field that you received copy of sketch No. 28 giving further details in connection with cantilever chord splice 7-L and 8-L. You will notice that the two chords have a perfect bearing with each other at all ribs. Both chords having one bent rib and not one chord only as we first understood.

(Signed) John Sterling Deans.

To which Mr. Cooper replied as follows:

Cooper to Deans, Aug. 21, 1907.

Dear Sir: I received copy of sketch of joint 7 and 8-L two days ago.

I wrote Mr. McLure last week telling him none of the theories as to how this bending occurred were logical. That my theory was a blow on this rib after the two sections were in contact and that it probably was done in moving those suspended beams used in erecting. To examine carefully to see if he could find any evidence of this, he has not yet reported. He did report a similar bend at L-8 and 9 west truss in same rib, but of less amount.

I still believe this bend can be partly removed by use of long bolts with threads at each end, outer rib being stiffened to prevent its bending. If it can be pulled nearer straight, stays or bolts must be provided to hold it against future movement.

I cannot consent to let it go without further action as the rivets in the cover splices would not satisfy the requirements to my mind.

(Signed) Theodore Cooper.

This letter was acknowledged by Mr. Deans on Aug. 23:

Deans to Cooper, Aug. 23, 1907.

Dear Sir. Joint 7-L and 8-L south cantilever arm. Referring to your letter of Aug. 21, I notice you expect to hear again from Mr. McLure. As soon as you have this report kindly let us hear from you again, and oblige. (Signed) Jno. Sterling Deans.

On Aug. 26 Mr. Cooper wrote the following letter:

Cooper to Deans, Aug. 26, 1907.

Dear Sir: Mr. McLure reports that he can find no evidence of the bent ribs having been hit and does not think they could have been struck. This only makes the mystery the deeper, for I do not see how otherwise the ribs could have been bent.

When convenient I would like to discuss with Mr. Szlapka the best means of getting these ribs into safe condition to do their proper work.

(Signed) Theodore Cooper.

This was acknowledged Aug. 27 by Mr. Deans:

Deans to Cooper, Aug. 27, 1907.

Dear Sir: Chord splice 7 and 8 cantilever arm south side. Replying to your letter of Aug. 26, I will have Mr. Szlapka call to see you first opportunity to discuss this question. He will write you later the day he will be in New York. (Signed) Jno. Sterling Deans.

This was the last that transpired with regard to the bent ribs at joint 7-L and 8-L cantilever arm, and it is plainly indicated that no one except Mr. Cooper looked upon this matter as serious or as indicating any constitutional weakness. It will be noted that the bends at 7 and 8 were reported on Aug. 6, the bends at 8 and 9 discovered on Aug. 12, and that both bends were in the west truss; that previously from time to time chords with ribs more or less wavy had been reported, and Mr. McLure gave it as his opinion that these bends were caused by stress since erection, because he was sure they were straight when erected, while Mr. Deans thought the bends were made in the shop.

While Mr. Deans after Mr. Szlapka's return gives certain information as to the bend on the 7 and 8 splices Mr. Szlapka (p. 964) states that on his visit to the bridge he did not examine this splice, and further says that during none of his three visits to the bridge did he examine any chords.

Mr. Kinloch states in his evidence that he did not notice these bends at the 7 and 8-L joints when the bottom cover plate was first removed and that he felt confident that these distortions took place after the removal of the cover plate.

It seems clear from the above that Mr. Cooper's statement that the delicacy of the joints was not sufficiently appreciated by the Phoenix Bridge Co. is substantiated. Mr. Szlapka was on the ground and made no special examination in the matter and Mr. Deans endeavored to throw the blame for the distortions entirely on the shop work. No evidence has been shown to us to prove that Mr. Deans had any grounds for this assertion, and his inspector, Mr. Morris, was in possession of information that indicated that there was no great probability that such an error could have escaped detection.

On Aug. 20, Mr. Kinloch discovered that chord 8-R of cantilever arm was bent, and afterwards found that 9-R and 10-R also showed distortion. He called Mr. Birks' attention to this condition, but neither of them considered it of importance. Mr. McLure was ill and did not see these bends until several days after they were found (Aug. 23), but Mr. Yenser was made aware of them. On Aug. 23 the joint at chords 5-6R of cantilever arm was found to be off on one center rib ½-in. at bottom, the offset running to nothing at top. Mr. Kinloch visited chord 8-R daily for several days and imagined that the bend was becoming greater, all four ribs being bent but not alike.

THE FINAL TROUBLE.—The bend* in chord 9-L anchor arm was discovered about 9.30 a. m. Aug. 27, to have greatly increased, it having been previously noted and being under observation. Owing to the fact that the 25th was a Sunday and that there was practically no work done on the 26th, it is doubtful whether this chord was examined between the 24th and the 27th. Mr. Kinloch, who made the discovery, in his evidence says:

Q. Please relate the occurrences following your discovery of the bent chord on Aug. 27?

A. Immediately after discovering the bend I brought the matter to the attention of Mr. Yenser and Mr. Birks and with them re-examined both chord A 9-L and several other lower chord members. We did not know what to make of the matter and then went up to our office and arranged with Mr. McLure to have the deflections of the suspicious chords measured. This measurement, which was made by Birks, McLure and myself, showed the extent of the deflections; and their cause, and their ultimate result immediately became a matter of very active discussion. Mr. Birks expressed himself definitely as being of opinion that there was no danger and endeavored to persuade me that the bend had always been in the chord. Mr. Yenser and I were uneasy and considered the matter serious, and finally suggested that Mr. McLure and Birks should go to New York and Phoenixville for advice. It was considered that the matter could not be satisfactorily explained by telegraph or telephone and none of us expected immediate disaster. Mr. Birks and Mr. McLure did not welcome our suggestion saying that they would only be laughed at on arrival and it was finally agreed to refer the matter of sending to headquarters to Mr. Hoare, who decided in favor of our suggestion. Mr. Hoare visited the bridge on the Wednesday and spent most of the day there. He appeared very anxious that I should abandon my position of being positively convinced that the bend had occurred since the erection of the cantilever arm was completed and argued both this and some possible method of strengthening the chord by bracing several times with me. I was somewhat excited and much annoyed at the unwillingness of all the engineers to accept my statement of facts and on both Wednesday and Thursday avoided further discussion of the matter as much as possible. It was understood that Mr. McLure would immediately wire me if Mr. Cooper took a serious view of the situation but this he failed to do. Mr. Birks, however, told me on the morning of the 29th that he had been advised by 'phone from Phoenixville that they had a record which showed that the bends had been in the chord before it was shipped from Phoenixville and that he had just advised Mr. Hoare by telephone at the request of Mr. Deans to that effect.

As soon as the measurements above referred to were made, it was recognized by Mr. Yenser and the inspectors that they were face to face with a crisis. Mr. Yenser announced his intention of stopping erection until he had referred the matter to Phoenixville. The measurements were plotted and were reported by mail to Mr. Cooper and to Phoenixville, these reports being delivered on the morning of the 29th. Owing apparently to anxiety already existing among the workmen, it was not considered wise to use either telegraph or telephone. As suggested by Mr. Kinloch, Mr. McLure reported the matter fully to Mr. Hoare on the evening of the 27th, the delay of about 12 hours being accounted for by the making and plotting of the measurements and the necessity of using a personal messenger as it was not wished to report particulars over the telephone.

It is clear that Mr. Yenser, Mr. Kinloch and Mr. McLure were very much alarmed but Mr. Birks could not be convinced that the bends had recently taken place. He knew better than anyone else on the work the care with which the calculations and designs had been made, he was familiar with the experience and abilities of the designers, and could calculate that the stresses were then far below the expected maximum.† To engineers the force of such reasoning is very great and we do not consider that the confidence Mr. Birks placed in his superiors was in any way unusual or unreasonable. There was no misunderstanding, however, on his part; he realized that if the bends had not been in the chord before it was erected, the bridge was doomed, and although Mr. McLure had evidence that the bends had increased more than 1 in. in the course of a week, although Mr. Kinloch was positive that the bends had very recently greatly increased, and although Mr. Clark stubbornly maintained that the chord

*Not before mentioned in the report.—Ed.

†The stress then was about 18,000 lbs. per sq. in., as against 21,200 lbs. for dead, live and wind. See testimony of P. L. Szlapka, Eng. News, Nov. 28, 1907, p. 585, col. 1.—Ed.

was absolutely straight when it left Chaudiere yard, Mr. Birks still strove to convince himself that they must have been mistaken.

Mr. Hoare evidently concluded that the matter was too serious for him to settle by any offhand decision, and approved Mr. McLure's mission to New York, wisely requiring that he should get all possible facts before leaving, so that Mr. Cooper need not wait for further information on which to base a decision. The text of Mr. McLure's report of Aug. 27 is as follows:

McLure to Cooper, Aug. 27, 1907.

Dear Sir. I enclose sketches showing condition of bottom chord sections 606—9-L of south anchor arm and 621—9-R and 8-R of south cantilever arm, as found from measurements made today by the Phoenix Bridge Co.'s Asst. Engineer and myself, by stretching a line from batten plate to batten plate as indicated on the sketches and measuring from this line held taut, to each rib, top and bottom. It was noticed this morning that these chords were bent in this manner, as it is very evident to one walking over them, and as it looked like a serious matter, we measured them.

Although a number of the chords originally had ribs more or less wavy, as I have reported to you from time to time, it is only very recently that these have been in this condition, and their present shape is undoubtedly due to the stress they are now receiving. Only a little over a week ago, I measured one rib of the 9-L chord of anchor arm here shown, and it was only ¾ in. out of line. Now it is 2¼ ins.

. . . You will note that chords 606—9-L and 621—9-R have all ribs bent in same direction while 621—8-R has its ribs bent in reverse curves. These bends had became so apparent by today that the gangs riveting at these points noticed them, and called Mr. Kinloch's attention to them.

This matter is being reported in this mail, with sketches from the same measurements, to the Phoenixville office, and the erection will not proceed until we hear from you and from Phoenixville.

(Signed) N. R. McLure.

Wednesday, Aug. 28, was a day of waiting and uncertainty. Mr. Yenser had changed his mind during the night and in the morning continued erection. The men were uneasy and alarmed and the officials were anxiously awaiting instructions from Phoenixville or New York. Mr. Yenser's decision to continue work was laid before Mr. Hoare, upon whom, as Chief Engineer, the final responsibility for every step taken rested, decided that he had acted wisely. Mr. Hoare makes this clear in the following letters to Mr. Cooper:

Hoare to Cooper, Aug. 28, 1907.

Dear Sir: I wired you today as under:

> Have sent Mr. McLure to see you early tomorrow to explain letter mailed yesterday about anchor arm chords.

Also the following message to the Phoenix Bridge Co.:

> Mr. McLure will call tomorrow to explain Birks' letter re anchor arm chords, will see Mr. Cooper first.

Regarding this matter I thought it best for McLure to go at once to be able to explain matters and answer questions. He did not have much time for extended investigation before leaving.

I have been at the bridge all day trying to get some evidence in connection with the bending of the ribs in this chord. Mr. Kinloch noticed it for the first time yesterday and all inspectors declare that no such pronounced distortion existed a few weeks ago. Mr. McLure made measurements yesterday afternoon and brought them to my house late last night, and stated that the erection foreman hastily concluded that he would not continue erecting today, which alarmed me at the time. Upon arriving at the work this morning he thought better of it and decided to go ahead, at the same time asking me if it would be all right. After ascertaining that the effects from moving the traveller ahead and proceeding with the next panel would be so insignificant I requested him to continue, as the moral effect of holding up the work would be very bad on all concerned and might also stop the work for this season on account of losing the men. From further investigation during the day I cannot help concluding that the metal received some injury before it was erected as the corresponding chord in the same panel and stressed the same is in good condition. These panels are being stressed today, approximately, about 7/10ths of their maximum, and it is difficult to believe that this is the entire cause of the distortion. Now and again a rib in certain members is found to be a trifle longer than another, which, when compressed, might cause a trifling kink in it. There are a few examples of this. The chord in question, when being lifted to the cars in the storage yard broke loose from the grips one end of which fell a distance of 6 ft. on to timber sills, the other end fell a distance of 2 ft. on to a block of eyebars. In falling it fell over on its side breaking one of its angles on the north end splice and twisting some of the lacing bars, all of which were renewed. After this the inspectors reported the ribs perfectly straight. On account of this chord falling on to two rigid higher points at ends, with no support in the middle but soft material, the conclusion would be that the deflection would be downward, as a matter of fact the evidence shows that it was in the opposite direction. Since Mr. McLure left, Mr. Birks has made careful examination of the chord and states that the actual bending commences at the south splice and was not confined entirely to the length between the bottom plates, where the lacing angles are used. As the foremen and inspectors declare that these defects were not noticeable until recently, perhaps the stress in this chord has made previous defects more pronounced. I thought I would give you the above story from further investigation by tonight's mail to help you to come to some conclusion. (Signed) E. A. Hoare.

Hoare to Cooper, Aug. 29, 1907.

Dear Sir: Mr. Birks has just called me up on the telephone from the bridge and states that he has received a message from Phoenixville stating that they have positive evidence that the chord was not straight before it left the shops. This possibly clears up the mystery why the deflection was in the opposite direction to what it should have been, due to its fall in the storage yard. Mr. Birks has wired that information to Mr. McLure at your office. Mr. Birks further stated that he is positive that the chord ribs were more or less out of line when the splice at the south end was riveted up in the bridge. (Signed) E. A. Hoare.

Hoare to Cooper, Sept. 2, 1907.

Dear Sir: I thank you for replies to all our messages. I am sorry that you are not well and of course this appalling disaster has made you feel a thousand times worse.

Mr. Berger will answer our purpose very well for the present. The investigating Commission may find it necessary later to interview you in New York, due notice of which will be given you.

I wish to correct a misstatement in my letter to you of Aug. 28, which was written late and very hastily to confirm telegram and conversation with Mr. Birks about the chord under discussion. The statement in my letter as follows

> Mr. McLure made measurements yesterday afternoon and brought them to my house late last night and stated that the erection foreman hastily concluded that he would not continue erecting today, which alarmed me at the time. Upon arriving at the work this morning he thought better of it and decided to go ahead, at the same time asking me if it would be all right. After ascertaining that the effects from moving the traveller ahead and proceeding with the next panel would be so insignificant I requested him to continue as the moral effects of holding up the work would be very bad on all concerned and might also stop the work for this season on account of losing the men.

is to some extent a misstatement of facts and not clearly stated, due to too much haste, and which I wish now to correct as under:

> Upon arriving at the work that morning the foreman told me that he had considered it during the night and had already removed the traveller forward asking myself, Mr. McLure and Mr. Birks if we thought that what he had done would do any harm. We all thought that it would not as they stated it would only add 50 lbs. to the square inch to the chord in question. We all thought at the time that to discontinue the work would entirely stop the work for this season as the men would not wait and would go elsewhere to prepare for the winter. As stated in my last letter strictly speaking I did not request the foreman to continue the work, as he had already done so; at the same time we thought there was no immediate danger in adding so small a load. This letter more clearly states the conversation between us, and I am sorry that I have misstated in my hurry, one or two points which would be more or less confusing. (Signed) E. A. Hoare.

It was clear that on that day the greatest bridge in the world was being built without there being a single man within reach who, by experience, knowledge and ability, was competent to deal with the crisis. Mr. Yenser was an able superintendent, but he was in no way qualified to deal with the question that had arisen. Mr. Birks, well-trained and clear headed, lacked the experience that teaches a man to properly value facts and conditions, and Mr. Hoare, conscious that he was not qualified to give judgment, simply assented to the courses of actions that had been determined on by Messrs. Yenser and Kinloch and made no endeavor to make a personal examination of the suspected chords.

Some measurements were made to test the stability of the main pier, but no one seems to have thought of testing the span for alinement or levels, and above all, to measure the chords again to see if they showed any increase of deflection. Mr. Hoare discussed some means of bracing the chords but decided to postpone action until Mr. Cooper was heard from. At Mr. Hoare's request Mr. Birks inspected the chord A 9-L and the A-L 8-9 joint carefully and his observations tended to reassure both Mr. Hoare and himself, as he thought, that he found evidence of original crookedness in the chord.

His report to Phoenixville, which was received on Aug. 30, reads as follows:

Birks to Phoenix Bridge Co., Aug. 28, 1907.

Dear Sirs: I have made a further investigation of chord 9-A, and beg to report following additional data: The bend in the chord starts at the faced splice at the shore end and not at the edge of the splice batten. It appears from this that at least a large portion of the bend was in the chord when the top and bottom splice battens were riveted early in June. This and the fact that the lacing angles are not disturbed leads me to believe that the ribs were bent before erection in spite of the fact that Mr. Clark and Mr. Kinloch think all ribs were straight when the chord was repaired. From the evidence so far, I do not think we are justified in assuming it to be a fact that the ribs of any of the chords have buckled since erection, and Mr. Yenser has come to the same conclusion. (Signed) A. H. Birks.

After he had made his examination, Mr. Birks called Mr. Kinloch and waited at track level, while Mr. Kinloch went down to the chord and checked Mr. Birks' observations. After careful discussion with Mr. Kinloch of what was then done we are forced to conclude that the sketch in Mr. Birks' letter shows only his personal idea of the shape and extent of the existing distortion and cannot be considered as furnishing data on which to base engineering conclusions, as no actual measurements were taken.

On Aug. 29 Mr. Birks' report of the 27th inst. was received at Phoenixville and was immediately discussed by Messrs. Deans and Szlapka and Milliken. It was finally decided that it was safe for the work to proceed and a telephone conversation took place between Messrs. Milliken and Yenser and another between Messrs. Deans and Birks. Mr. Szlapka had made some calculations and Mr. Birks reported his observations of Aug. 28. Messrs. Yenser and Birks were assured that the office approved their action in continuing work of erection and Mr. Birks was told to tell Mr. Hoare that the bends had been in the chords before they left Phoenixville. This Mr. Birks did. Mr. Deans also telegraphed Mr. Hoare as follows:

Deans to Hoare, Aug. 29, 1907.

McLure has not reported here; the chords are [illegible] condition they left Phoenixville in and now ha[illegible] less than maximum load.

Mr. Hoare had telegraphed to both Mr. Co[illegible] and Mr. Deans on Aug. 28, advising them of Mr. [illegible]re's mission. Mr. Deans has since explained that his [illegible]ram did not refer to the chords measured on the 2[illegible] but after considering the circumstances, we are enti[illegible]sat-isfied that Mr. Hoare was justified in thinking [illegible]t it did, and in so doing he was confirmed by M[illegible]irks telephone message previously received.

From the time these assurances were received, [illegible]iety at the bridge practically ceased, and there is no [illegible]dence that any further measurements were made to d[illegible]mine the movements of the suspected chords. As Mr. [illegible]oare expressed it:

> I felt quite comfortable that day about it. I [illegible]w it could not be long before the matter would be ta[illegible] up.

Shortly after 11 a. m. on Aug. 29, Mr. Cooper [illegible]hed his office and found Mr. McLure there. After [illegible] brief discussion Mr. Cooper wired to Phoenixville as [illegible]ows:

Cooper to Phoenix Bridge Co., Aug. 29, 1907, 12.[illegible] p. m.

Add no more load to bridge till after due consid[illegible]ration of facts. McLure will be over at 5 o'clock.

This message was received at Phoenixville at 1.[illegible] p. m. Mr. Cooper has explained in his evidence that he was not aware at the time that erection was proceeding. Mr. McLure having advised him to the contrary, and that he telegraphed to Phoenixville instead of to Quebec because he thought action would be more promptly secured by so doing.

Mr. McLure had promised to wire Mr. Cooper's decision to Mr. Kinloch immediately but he did not do so.

Mr. Deans reached his office about 3 p. m. and found Mr. Cooper's telegram there. He arranged for Mr. Szlapka and Mr. Milliken to be on hand to meet Mr. McLure, but otherwise took no action. After Mr. McLure arrived there was a brief discussion during which Mr. McLure mentioned that he had received a wire from Mr. Birks giving him the result of that gentleman's observations on Aug. 28. It was decided to postpone action until the morning and to await the arrival of Mr. Birks' letter of Aug. 28. This decision was made almost at the minute that the bridge fell.

CONCLUSIONS AS TO THE EVENTS CAUSING THE COLLAPSE.

As a conclusion reached from the evidence and from our own studies and tests, we are satisfied that the bridge fell because the latticing of the lower chords near the main pier was too weak to carry the stresses to which it was subjected, but we also believe that the amount of those lattice stresses is determined by the deviation of the lines of center pressure, from the axes of the chords, and this deviation is largely affected by the conditions at the ends of the chords. We must therefore conclude that although the lower chords 9-L and 9-R anchor arm, which, in our judgment, were the first to fail, failed from weakness of latticing, the stresses that caused the failure were to some extent due to the weak end details of the chords, and to the looseness or absence of the splice plates, arising partly from the necessities of the method of erection adopted, and partly from a failure to appreciate the delicacy of the joints, and the care with which they should be handled and watched during erection. We conclude from our tests that owing to the weakness of the latticing, the chords were dangerously weak in the body for the duty they would be called upon to do. We have no evidence to show that they would have actually failed under working conditions had they been axially loaded and not subject to transverse stresses arising from weak end details and loose connections. We recognize that axial loading is an ideal condition that cannot be practically attained, but we do not consider that sufficient effort was in this case made to secure a reasonable approach to this condition. The Phoenix Bridge Co. showed indifferent engineering ability in the design of the joints and did not recognize the great care with which these should be treated in the field.

We consider that Mr. Deans was lacking judgment and in sense of responsibility when he approved of the action of Mr. Yenser in continuing erection, and when he told Mr. Birks and Mr. Hoare that the condition of the chords had not changed since they left Phoenixville.

No evidence has been produced before the Commission in proof of the correctness of this statement about the chords, and Mr. Szlapka's calculations as stated in the following letter showed that the rivets were even then loaded to their maximum specified stress of 18,000 lbs. per square inch.

Holgate to Phoenix Bridge Co., Jan. 24, 1908.

Gentlemen: Will you please file with the Commission a copy of the calculations made by Mr. Szlapka on Aug. 29, 1907, and which are referred to on pages 967 and 968 of the evidence.

As we are nearing the completion of our report, we would esteem it a favor if you would have this information sent to us immediately.

It is possible that you may not have an exact copy of these calculations but no doubt they can be duplicated and Mr. Szlapka's certificate to this effect will be sufficient.
(Signed) Henry Holgate.

Deans to Holgate, Jan. 31, 1908.

Dear Sir:—Replying to your letter of Jan. 24, I enclose herewith letter from Mr. Szlapka of this date giving calculations similar to that made on Aug. 29, regarding chord 9-L south cantilever arm.
(Signed) Jno. Sterling Deans.

Szlapka to Deans, Jan. 31, 1908.

Dear Sir:—Referring to Mr. Holgate's letter of Jan. 24, addressed to the Phoenix Bridge Co., I beg to give you below the calculations similar to the one made on Aug. 29, 1907, referring to chord 9-L south anchor arm.
Taking 1½ in. as the average reported curvature of chord 9-L we have:

$$\frac{WL}{4} \times 12 = 780 \text{ sq. ins.} \times 18{,}000 \times 1\tfrac{1}{2} = 21{,}060{,}000\text{-in. lbs.}$$

$W/2 = 61{,}600$ lbs.

$$\text{Stress in each lattice } S = \frac{61{,}600 \times 1.4}{4} = 21{,}600 \text{ lbs.}^*$$

(Signed) The Phoenix Bridge Co.,
per P. L. Szlapka.

The theory underlying these calculations is very questionable, but it was adopted in the design of the bridge and we cannot understand why its warning was so entirely disregarded in the face of the consequences that might result.

With reference to Mr. Cooper's telegram, Mr. Deans knew that he was in possession of later information from the bridge than had reached Mr. Cooper and therefore decided to wait for Mr. McLure and afterwards for the arrival of Mr. Birks' letter of Aug. 28 before taking action. The whole incident points out the need of a competent engineer in responsible charge at the site.

Mr. Hoare was the only senior engineer who was able to reach the structure between Aug. 27 and Aug. 29. He was fully advised of the facts, yet did not order Mr. Yenser to discontinue erection which he had power to do; we consider that he was in a much better position than any other responsible officer to fully realize events that had occurred, and his failure to take action must be attributed to indecision and to a habit of relying upon Mr. Cooper for instructions.

We are satisfied that no one connected with the work was expecting immediate disaster, and we believe that in the case of Mr. Cooper his opinion was justified. He understood that erection was not proceeding; and without additional load the bridge might have held out for days.

Our tests have satisfied us that no temporary bracing such as that proposed by Mr. Cooper could have long arrested the disaster; struts might have kept the chords from bending, but failure from buckling and rivet shear would soon have occurred.

*This appears to be a calculation of the end shear produced by a transverse load at the middle giving the same center moment as results from the load of 780 × 18,000 lbs. when the center deflection is 1½ ins.—Ed.

THE TYPHOID FEVER EPIDEMIC AT WATERTOWN, N. Y., IN 1904.

The years 1903 and 1904, as many of our readers will remember, were prolific with typhoid epidemics. One of the most interesting of these occurred at Watertown, N. Y., early in 1904. After an unfortunate delay the control of the epidemic was put in charge of Dr. George A. Soper, M. Am. Soc. C. E., of New York City. A paper outlining the epidemic and the methods employed to suppress it was presented to the New England Water Works Association on March 11, 1908, by Dr. Soper. The paper in full will appear in the Journal of the association.

From a table presented in Dr. Soper's paper it appears that for the 19 years 1885-1903, inclusive, the average typhoid death rate of Watertown was 71 per 100,000 population, against an average of 25 for the entire state. The Watertown rate never fell below 35 and was as high as 169 in one year and somewhat over 100 in two other years. For the 19 years, typhoid caused 4.17% of all the deaths in Watertown. In the epidemic year, 1904, the Watertown typhoid death rate was 194 per 100,000 and the typhoid deaths were 12.81% of those from all causes.

A mechanical filtration plant was already under construction when the 1904 epidemic broke out. The plant was completed and put in operation during 1904. In 1905 the typhoid death rate fell to 24 per 100,000, but in 1906 it rose to 50 and in 1907 it was 37. Dr. Soper made no comment on the high rates of 1906 and 1907 and their relation or otherwise to the filtration of the water supply.

The cause for the 1904 epidemic, as of the high typhoid rates during the preceding years, has been generally attributed to the pollution of the public water supply. As early as 1895, when the typhoid rate was 169 per 100,000, the late Prof. Wyatt Johnston, then connected with McGill University, Montreal, reported that the water supply was the undoubted cause of the high typhoid rate and predicted that typhoid would prevail until an improved water supply was secured. Investigations made at that time showed numerous sources of pollution between the water-works intake and Carthage, a distance of 17 miles. Rules for the sanitary protection of the Black River, from which the water supply of Watertown is drawn, were made in 1896 by the State Board of Health at the request of the local water commissioners. These rules were never put into effect, owing, it appears, to the fact that the expense of so doing, together with any accompanying financial loss to mills and villages, would have fallen on the city.

The Black River, it may be noted here, has a drainage area of 1,887 sq. mi. above the water-works intake. Much of this drainage area is sparsely populated and mountainous, but for 17 miles above Watertown the drainage area is "much more thickly populated" and is a "steep, narrow valley." Between Watertown and Carthage there are many mills, factories and dwellings on the river banks, and these, as already intimated, contribute largely to the pollution of the stream.

Immediately preceding the epidemic of 1904 there was a long cold spell with heavy snow, followed by a warm south wind and rain. This thaw occurred the latter part of December, 1903. Numerous cases of typhoid fever began to be reported by physicians in January.* There was no complete reporting of cases during the outbreak, but so far as the records go there was a total of 595 cases. The deaths to May 1, 1904, numbered 44, making a case fatality of 7.4%. The cases were distributed throughout the whole city, the poorer sections suffering the most. All the evidence collected placed the responsibility for the outbreak upon the public water supply.

Although the subsequently corrected reports from physicians showed a total of 234 cases up to Jan. 29 and 10 on Jan. 30, no strong measure to combat the outbreak seems to have been taken until Jan. 30, on which date the Health Officer notified the State Department of Health of the conditions prevailing. On Feb. 1, when the cases, in round numbers, numbered 250 the local Board of Health decided to investigate the cause of the outbreak. On Feb. 8, when the total number of cases reported for January and that far in February was 330, the Health Officer was authorized "to employ a sanitary expert at once to investigate the situation and take such measures as may be reasonable and necessary to eliminate the epidemic."

The State Department of Health did not respond to the notification of the Health Officer, apparently, for about two weeks; at least it was not until Feb. 13 that a visit to the city was made by Prof. O. H. Landreth, Consulting Engineer of the State Department of Health. Up to the night of that day, a total of 366 cases had been reported, but nevertheless the representative of the state remained in the city only one day. On Feb. 20, Professor Landreth again visited Watertown, remaining two or three days. [We have supplemented Dr. Soper's paper, as abstracted in this paragraph, by statements made in Mr. Fuller's article, already mentioned in the foot-note.—Ed.]

Desirous of securing continuous expert work in the control of the outbreak, the city of Watertown finally engaged Dr. Soper to take charge of an active campaign against the fever. His general method of procedure may be set forth by the following quotation from his paper:

> The measures for controlling the epidemic which were carried out at Watertown during my connection with the city were largely based on the results of Koch's now famous studies at Trier, and the opinion which had grown out of my experience, that typhoid is not only infectious, but contagious, and transmissible from person to person.
>
> The immediate objects of the campaign were the prevention of infection through the river water and from cases of typhoid already in the city. It was accepted by me as abundantly proved that the water supply had given rise to the original cases.
>
> I advised that every typhoid patient be sent to hospital or strictly isolated at home. No patient should be discharged from medical care until bacteriological tests showed that his excretions were no longer dangerous. All mild and suspicious cases of fever should be treated like typhoid. Secondary sources of disease, such as contaminated wells and milk supplies, were to be guarded against. All infectious matter should be destroyed by disinfection at its source. It was not practicable to put all these measures into effect; at least, not at once; nor ever with that completeness which was desirable. They were, nevertheless, kept always in mind and give the key to the principal work which was done by the Board of Health during my connection with it.
>
> The sanitary work of the inspectors acting under the direction of the State Department of Health on the drainage area of the Black River and the natural flow of the river during two months of time seemed to me to have been sufficient to have removed every source of danger from the public water supply which it was practicable to remove. Still, in order to obtain the greatest measure of safety procurable, various steps were taken to secure protection from the public water supply. The distributing mains were flushed from the hydrants, one section of the city being taken at a time, and the work done in a thorough manner. The people were urged to continue to boil that portion of the water which it was necessary to use for drinking, dish-washing, and other purposes which might, by any possibility, lead to infection. The builders of the filtration plant were requested to push the completion of their work so that the plant could be made available at the earliest date.
>
> Spring water of known purity was distributed by tank wagons of 100 to 400 gals. capacity each, at a cost of 1 ct. per gal., which was nearly enough to cover the expense. The tanks were sterilized at least twice a week by means of steam. Water tickets were sold in quantity but were not allowed to be re-used. Besides supplying pure spring water, private wells were inspected, samples collected for analyses, and suspicious wells closed.
>
> One of the most important parts of Dr. Soper's work was to supervise hospitals for the treatment of typhoid patients. This was made all the more difficult on account of the fact that there were many cases of malignant erysipelas in connection with the typhoid, as frequently happens. To supplement the overcrowded existing hospital facilities, a newly finished but unoccupied high school was turned into a hospital, against the determined opposition of the Board of Education. The use of disinfectants in the hospital, and other related precautions, are described in the paper as follows:
>
> The disinfectants used were fresh milk of lime for the stools and urine, and 1 to 1,000 bichloride of mercury solution for cloths, hands, and floors. Sheets, pillow cases, and the garments of the patients, when removed, were placed in cloth bags at the bedsides and taken at once to the cellar where they were disinfected before being washed. Sputum and cloths soiled with excreta, urine, or sputum were put into paper bags at the bedsides and removed in iron ash cans to a furnace in the building and burned. The cups, dishes, spoons, and other articles used in feeding the patients were kept separate for each case and regularly sterilized by boiling. The floors of all the wards were mopped with 1 to 1,000 bichloride each day. No sweeping was permitted in any part of the building. Care was taken to avoid the production of dust by the use of damp cloths. No receptacles for milk or water were allowed to leave the building. The hospital was furnished with a fresh supply of spring water daily.
>
> At both of the hospitals picked graduate nurses were employed. Of 97 cases treated at the high school hospital only 1 died. None of the employees contracted the fever.
>
> A bacteriological laboratory, for the examination of water, milk, blood and urine, with new and complete equipment, was installed. This was put in charge of Dr. Herman Requl, of the University of Chicago, who was supplied with "enough help to enable him to turn out prompt and accurate reports." All laboratory work was done at the expense of the city.
>
> The use of disinfectants at the hospitals has already been described. The general use of disinfectants throughout the city is also worth describing in the language of the paper:
>
> Disinfection was practiced in several ways. At the outset an effort was made to introduce uniform methods of disinfection in as many of the fever houses as possible. Because of the unreliability of the proprietary disinfectants sold in the shops, the Board of Health established a central disinfectant bureau and from this point distributed, without cost to the consumers, disinfectants throughout the city. Several wagons were employed to carry freshly slaked lime and concentrated bichloride of mercury to each house in which a case of typhoid fever was known to exist. Every fever house was thus visited twice a week, sometimes oftener. The dis-

*The course of the outbreak up to the latter part of February was detailed in Engineering News for March 3, 1904, in an article prepared by Mr. W. E. Fuller, Assoc. M. Am. Soc. C. E., of Hazen & Whipple, New York City, who was at that time resident engineer in charge of the construction of the filter plant and served as an inspector in the drainage area.

infectants which were sent out on the wagons were known as "white fluid" and "blue fluid," and were of such concentration that, upon adding to either four times its volume of water, it would be of proper strength for use. The milk of lime, or white fluid, when ready for use, was composed of one part of freshly slaked lime to eight parts of water. The bichloride of mercury solution employed consisted of one part of bichloride of mercury to one thousand parts of water; this was made acid with hydrochloric acid and colored blue with common washing bluing. Directions for using both of these disinfectants were printed in large type on stout sheets of cardboard and left at each house where the disinfectants were employed.

Fumigation with formaldehyde was performed by the Board of Health at each house after a case of fever unless there was good reason to believe that this precaution was unnecessary. The method of generating the formaldehyde first used was that regularly employed by the Watertown Board of Health. It consisted in the use of a lamp with paraform pastils from which the gas was expelled. Later, because of the large number of houses which needed to be fumigated, a more rapid method was adopted. After the room had been closed as air tight as possible, and rugs, draperies, bedding, and other similar articles had been hung on chairs or suspended in the middle of the room, a large sheet was hung up. From a small watering pot there was then poured upon this sheet a solution of formalin of 40% strength, in the proportion of at least 3 pints for every 1,000 cu. ft. of air space, not allowing for the space taken up by the furniture and other articles in the room. After 24 hours all the windows were opened and the place thoroughly ventilated for at least two days. A careful scrubbing of the woodwork with soap and water and a brushing of the upholstery and drapery followed.

As a test of the efficiency of the fumigation, threads freshly impregnated with typhoid bacilli from 24-hour broth cultures were exposed in the room during the vaporization of the formaldehyde. After the disinfection the threads were immediately placed in sterile broth in the laboratory. If there was no growth this was taken to mean that the fumigation had probably been sufficient to destroy such bacilli of typhoid as may have been in the room as a result of its occupancy by the typhoid fever patient.

A considerable number of cases of typhoid had occurred at the village of Deferiets, located about ten miles above the intake. This was a new village established by the St. Regis Paper Co., and provided with a sewerage system discharging untreated sewage into the Black River. The officers of the company cooperated with the officials of Watertown, under Dr. Soper's direction, to exclude infectious matter from the sewers.

Dr. Soper concludes his paper with acknowledgments to Mr. Charles F. Bingham, Mayor of Watertown, to Mr. John B. Rogers, President of the local Board of Health, to Dr. E. S. Willard, Health Officer, and to Mr. E. J. DeLong, Principal Office Assistant.

Discussion on Dr. Soper's paper was opened by Prof. William T. Sedgwick, of the Massachusetts Institute of Technology. Dr. Sedgwick commented on the historic slowness of the race to learn from recorded facts, forcibly illustrated by the history of typhoid at Watertown. He laid special stress upon the importance of regarding typhoid as contagious. The continuance of high typhoid rates at Watertown since the introduction of filtered water, the speaker said, emphasizes anew the attention that must be given to residual typhoid, or that due to other causes than the public water supply. The speaker stated as his belief that the continued typhoid at Washington, since the slow sand filters were put in operation there, will yet be proved to be due to other causes than water, as has been urged in the course of editorial discussions in Engineering News.

Prof. C.-E. A. Winslow, of the Massachusetts Institute of Technology, discussed the environmental conditions which influence the prevalence of typhoid fever in different portions of the country. The chief of these is temperature. The figures recently compiled by Professor Winslow from the 1905 mortality statistics of the U. S. Census Bureau, show a relatively low rate for northern cities, a materially higher rate for those in the Central States, and a still higher rate for the Southern States, the latter rising to an average of about 80 typhoid deaths per 100,000. In making up these averages, the typhoid mortality among negroes was excluded, since it is known to be greater than among whites.

High temperatures, the speaker said, are favorable to the continued life of typhoid germs when the latter are not properly destroyed by disinfection, thus making more infectious matter available in hot weather than in cool. But this alone does not explain the high mortality in the hot weather, much of which is probably due to the depressing effect of heat upon the host of the typhoid germ. Recent studies by Colonel Roberts show that in India 68% of the typhoid fever in the British Army, among the British troops, occurs in hot weather, and only 32% in cool weather, while among the native troops the general proportions are reversed. As can be readily seen, the British troops are less resistant to infection in hot weather and the native troops in cool weather.

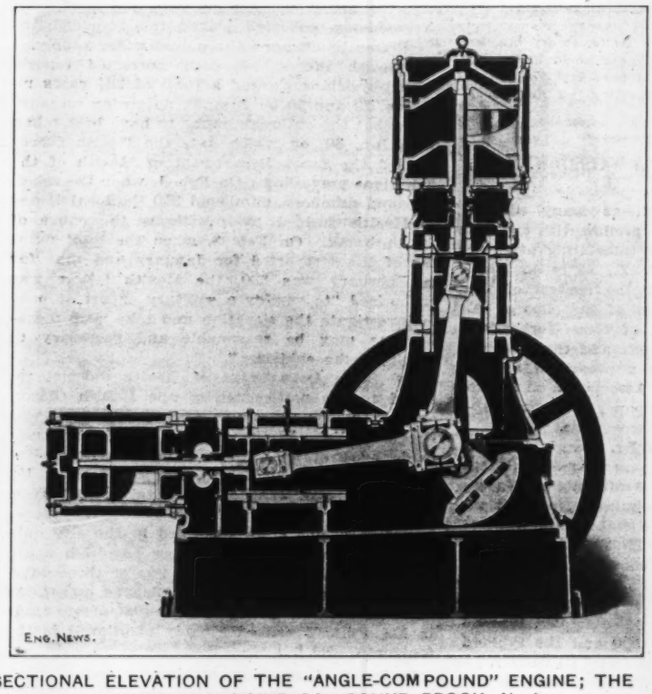
A HORIZONTAL-VERTICAL COMPOUND ENGINE IN SMALL-SIZED UNITS.

The accompanying illustration shows a sectional view of a new design of compound high-speed engine recently placed on the market by The American Engine Co., of Bound Brook, N. J. This design is stated to be the work of Mr. F. H. Ball, M. Am. Soc. M. E., and his son, Mr. F. O. Ball, M. Am. Soc. M. E., both of whom are well known as engine designers. It is evident that this engine is a combination of a horizontal high-pressure and a vertical low-pressure engine whose driving rods work on a single crank-pin. This idea itself is not new, although its application to such small power units has not been considered commercially advisable by other designers.

The valve gear of the high-pressure cylinder is a slide-valve gear operated in connection with a fly-wheel governor. The low-pressure cylinder valve gear is operated from an eccentric, which also operates the oil circulating system. The cross-heads of both cylinders are of a single piece, carrying no adjusting shoes, the adjustment being provided in the guides. One of each pair of guides is secured to the frame by screws, and is adjustable only by means of shims, but the other has a pair of screws at each support to provide for delicate adjustments, and the guide is securely held against these adjusting screws by bolts. The guides are carried in bored seats and projections on the back of the guides fit between supports cast on the frame so that any end thrust is resisted by the frame.

The method of attaching the counterbalance weight is seen from the accompanying illustration. It is claimed that by making the larger low-pressure piston of a light steel structure, having nearly the same weight as the smaller high-pressure cast-iron piston, this single counterweight, as shown, so balances the thrust of both sets of reciprocating parts that perfect balance can be obtained at four points in each revolution of the flywheel. Between these four points, naturally, the unbalance cannot be appreciable. It is stated, as an example of the running qualities of this type of engine, that a 160-h.p., 300 r. p. m., 11-in. stroke, direct-connected unit has been placed in the power plant of the makers at Bound Brook, N. J., resting on the concrete floor of the building with no special foundation and with no holding-down bolts. With the engine running on fluctuating loads, it is claimed, a new lead-pencil can be balanced on either cylinder.

It is intended also to build these engines in pairs with a direct-connected generator between. In such cases the outfits are to be used as double compound units when run non-condensing, or, when cooling water is available, as four-cylinder triple-expansion types. In the latter case, one horizontal cylinder would serve the high pressure; the other horizontal cylinder would act as the intermediate, and the two vertical cylinders would receive the low-pressure steam.



SECTIONAL ELEVATION OF THE "ANGLE-COMPOUND" ENGINE; THE AMERICAN ENGINE CO., BOUND BROOK, N. J.

GRADE REVISION ON THE CANADIAN PACIFIC RY.

In the description of the reconstruction of the Canadian Pacific Ry. between Field and Hector, B. C., in our issue of Jan. 23, the train load for the new line was incorrectly given, and there was also some inaccuracy as to the actual grades. From Mr. J. E. Schwitzer, Assistant Chief Engineer, we learn that the present maximum grade is 4.5% (compensated) instead of 4.4%, and is about three miles long, the balance of the distance varying from 3.5% to 4%. A greater compensation for curvature is allowed in the tunnels, on account of the probability of damp rails. On ordinary work the compensation is 0.04% per degree of curvature, while in the spiral tunnels 0.06% is used.

At the present time the rated load of four consolidation engines is a freight train of 710 tons, and when the grade revision is completed, it is expected that two engines of the same class will haul 980 tons. The manner in which this is figured out is as follows: Four engines weighing each 154 tons (616 tons total) are rated at 710 tons (1,326 tons total weight of train) on a 4.5% grade. Resistance on this 4.5% grade = 20 lbs. per ton for each per cent. of grade plus 5 lbs. rolling resistance, making a total of 95 lbs. per ton.

The total resistance on a 2.2% grade would be 44 + 5 = 49; 95/49 of 1,326 tons = 2,571 tons for four engines, or 1,285.5 tons as the total weight or train for two engines. Deducting 308 tons for the weight of the two engines gives a rating of 977.5 tons, or practically 980 tons.

Theoretically, the rating for these engines should be considerably increased, as the maximum tractive force per engine is 36,000 lbs., but it is considered safer to figure on the lower rating which has been adopted by the mechanical department.

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Mr. John F. Stevens, late Chief Engineer of the Panama Canal, has been widely quoted of late to the effect that the canal will not attract traffic enough when completed to make it a paying enterprise.

This is not exactly a new idea. The Isthmian Canal Commission of 1899-1901 made very careful investigations of the existing volume of traffic which would use an isthmian canal and of the rate of growth of that traffic. Their investigations showed that the canal might reasonably expect a traffic of about 7,000,000 tons by 1914. The tolls on this traffic would not return any considerable rate of interest on the nation's investment in the canal at the outset, but a steady increase in traffic may be reasonably expected.

Further, as the Commission of 1899-1901 pointed out, there are other considerations more important than revenue. The Pacific Coast for fully two decades has been urgently appealing for through water transportation to the markets on the Eastern seaboard without the double transfer of the rail journey across the Isthmus. By the time the canal is finished, lumber from the ports of Puget Sound and British Columbia will doubtless be demanded in enormous quantities by the Eastern States, so that the transcontinental railways could not begin to accommodate the traffic.

From the military side, the canal will silence those who clamor for duplicate navies on the Pacific and on the Atlantic; and if it will save the building of even a half-dozen battleships and cruisers in a decade, it will prove a very profitable investment.

Four of the men responsible for the gross frauds in furnishing the Pennsylvania State Capitol, by which the State expended $13,000,000 on a building which was only supposed to cost $4,000,000, were convicted of conspiracy on March 13, the conviction carrying with it a statutory maximum penalty of two years' imprisonment and a fine of $1,000. These and other accused parties have to await further trials on other specific charges in connection with these frauds.

It is not too much to say that the question whether law and order or anarchy shall rule in the State of Pennsylvania has hung upon the result of the trials concluded at Harrisburg last week. For years upon years, the fraud and corruption rampant in the State and municipal governments of Pennsylvania have been a stench in the nostrils of its decent citizens. Attempt after attempt to introduce better conditions has met with final defeat. It appeared that anyone with sufficient political influence in Pennsylvania could carry on highway robbery as a regular line of business and be safe from all interference. The defendants in these State Capitol frauds had the effrontery to claim that all their acts were perfectly regular and legal and that the sale of furniture to the State at a profit of 400% to 4,000% on its cost was done in such a manner that no law was infringed.

Happily this attempt to escape the consequences of their acts through technicalities availed nothing; and the conviction at Harrisburg is warning to every political malefactor in the State, who has his hand in the public treasury, that his crime may yet be exposed and punished.

In view of the backwardness of many of the Southern States in health-protective matters, it is a pleasure to record that the State Board of Health of Virginia is to be reorganized on an efficient basis and provided with an annual appropriation of $40,000, as compared with $4,000 heretofore, all of which small sum has not always been wisely expended. The new health department will consist of twelve unpaid physicians, and a paid health officer not a member of the board, upon whom active work will fall. This health officer must

> be versed in bacteriology and sanitary science and otherwise fitted and equipped to execute the duties incumbent upon him by law. He shall hold office for four years unless sooner removed by the government. He shall be vested with all the authority of the Board.
> * * *

The health officer is to have a salary of $3,500 a year and may appoint an assistant health commissioner at $2,500 a year, a bacteriologist at $2,500 and a clerk at $1,200. Additional clerks and assistants may be appointed by the commissioner, subject to approval by the board. The statute providing for this reorganization goes into effect on July 1, 1908.

The credit for passage of this legislation is very largely due to Dr. Ennion G. Williams, of Richmond, who, as a trusted correspondent of this journal says,

> almost single-handed and with absolutely nothing whatever to gain for himself, has with extraordinary ability, courage and personal inconvenience, brought about first a complete reorganization of the health department of Richmond, and now of the whole State of Virginia. For all this he is entitled to the thanks and respect of every good American.

We heartily endorse this statement, and add that there is abundant opportunity in other States for equally efficient and necessary work along the same line. This need is by no means confined to the South, but extends from Virginia southward and westward to and up the Pacific Coast, and back over the Rockies well to the eastward. Of course, there are exceptions, but as a rule the South and the West are still unprovided with efficient State boards of health; and this notwithstanding the fact that they have great and peculiar needs of the services that can be rendered by such boards.

LESSONS FOR THE ENGINEERING PROFESSION IN THE QUEBEC BRIDGE COMMISSION'S REPORT.

Seven months ago, when the half-completed Quebec Bridge superstructure crashed to destruction, we ranked it as the greatest of engineering disasters. The report upon this wreck, just made by the Canadian Commission of Engineers appointed to investigate it, is we believe the most notable investigation of an engineering disaster that the present generation, at least, has seen.

A very great responsibility was laid upon this Commission. The country, as well as the engineering profession the world over, desired to know not only the immediate cause of this terrible catastrophe, but the secondary causes which had contributed to bring it about. It was important to find the particular member whose yielding under stress brought down the whole structure in gigantic collapse; but it was far more important that engineers should know what were the defects of organization, or method, or men, or material that lay back of this failing member.

The Quebec Bridge disaster is a great object lesson to the engineering profession, and it is not a single lesson, but a score of lessons. Notwithstanding the large space which we have given to this disaster during the past seven months, the further space given to the Commission's report in our present issue is demanded by the important lessons which it contains—lessons not alone for the bridge engineer but for the whole profession.

The task laid before the Investigating Commission was one of extreme difficulty, not so much in tracing the sequence of events which led to the final great collapse as in the judicial weighing and collating of all the facts and distributing in equitable measure the burden of responsibility. In fact one lesson which deserves emphasis here is the importance of judicial fairness in work of this sort. It was not more important that the members of the Commission should have the technical qualifications to understand intricate questions of bridge design and quality of materials than it was that they should be able to fairly weigh men and their acts. A commission less expert might easily have been led astray on some of the technical questions involved. There was ample opportunity for this since the public prints, particularly in Canada, have teemed with discussions of the accident and its causes, which have borne a fair appearance of truthfulness and yet have been in the highest degree misleading—and some of these discussions, we regret to say, have come from engineers.

So, too, a commission less judicial in its make-up might have treated the disaster in a partisan way, and the result would not only have been injustice to some of the parties involved but cloaking of some of the important lessons to be taught. Here again the profession at large has not been guiltless. We have heard engineers use extravagant terms as to the blame which should be laid on this or that or the other party concerned, speaking without knowledge of the attendant circumstances, and assailing motives as well as deeds. Are we putting it too strongly when we say that no engineer with a spark of professional pride has a right to make public statements of this sort based on partial knowledge? The blame should be meted out where it belongs, certainly; and this the Commission has done; but let us not make the common mistake of going farther and concentrating burdens on one party or another for the sake of relieving some one else.

When the news of the great disaster was first telegraphed over the continent and engineers everywhere began to canvass the possible causes for the wreck, there was, we doubt not, a general consensus of opinion that the cause could not be laid to conscious, deliberate neglect on the part of the designers and builders. As we said in our editorial immediately following the disaster:

> The importance of the structure must have made every one concerned in its building feel the responsibility of securing, not only perfect design and excellent workmanship, but also material of absolute reliability.

The Commission's report establishes the truth of this prediction. All those concerned in the prosecution of the enterprise understood that they were engaged upon a structure of vast importance and gave to it their best endeavors. The work done throughout was of unusually high grade, with the sole exception of a few apparently small defects, whose importance no one realized until the disaster came like lightning from a clear sky.

The men who were chiefly responsible for the bridge, Cooper, Deans, Szlapka, Scheidl and the staff of the Phoenix Bridge Co., Norris and the whole organization of the Phoenix Iron Co., with the inspectors in shop and field, labored conscientiously and diligently, far beyond mere

perfunctory performance, to create a successful work. The details were looked after with marvelous industry and fidelity; and it was well that this was done, for faults in an engineering work are almost invariably faults in details. But in the pressure of the work upon details, defects in the fundamentals of design were overlooked.

At the very bottom of the design was the assumption of the dead load of the completed bridge; and yet this assumption was not checked by the weights of the members themselves, as taken from the shop drawings until it was too late to change the dimensions.

It was an error of administration—unrealized at the time, of course, but an error nevertheless—that subjected the designing engineers to such pressure of work that the chief designer, Szlapka, never found time to check his original dead-load assumption, and never required the detailing department to bring together the detail weights as the work went ahead. The resulting error of 30% in the weight of the structure, the Commission says, was enough to condemn the bridge had it not failed from another weakness.

It was an error of administration that put the entire engineering control of the design upon one overworked and underpaid Consulting Engineer provided with a single assistant. And it was because this man, sound and experienced both in theory and in practice, loaded himself with laborious detail work that he overlooked the fatal error in the assumed dead weight until the bridge was half built. Because of this, too, his judgment went to sleep when it ought to have condemned the fatally weak design for the great compression members.

It was a grave fault of administration which permitted the erection of this vast structure—a work of far greater complexity and difficulty than the profession has realized until this Commission's report appeared—without the constant supervision of a high-class bridge engineer constantly on the ground. We said in our issue of Sept. 19 last:

> If a huge piece of steel work like the Quebec Bridge can appear in perfect condition and yet collapse under static loads without warning, it is cause for great uneasiness among engineers.

We now know that the great bridge did give ample warning of the distress it was experiencing; and these warnings were seen and their significance was realized by the practical men on the ground. Authority, however, lay not in their hands but with a nominal Chief Engineer, in Quebec, 12 miles away, who was lacking in the technical knowledge and experience necessary to deal with such a problem. Real authority lay at New York, 600 miles away, with an engineer *who had never seen the structure for which he was actually carrying the entire engineering responsibility*, and at Phoenixville, still farther distant, where the engineers were relying on Cooper with implicit faith, and receiving the letters and telegrams from the subordinates at Quebec telling of the strange behavior of compression members without the smallest conception of its fatal significance.

Had there been no fundamental errors of design to create an emergency, a high-class resident bridge engineer clothed with authority to act in an emergency was still needed at the bridge site to see that the delicate work of erection was properly carried forward; and had such a man been on the spot, the lives of the 74 men killed in the disaster might have been saved.

We need not take space to enumerate all the lessons contained in the Commission's report. They are evident enough to every engineer who carefully studies it. There is one lesson, however, which deserves emphasis; and one which it behooves us as engineers to study in all humility.

And the lesson is the contrast between the practical man—the man whose only training was the training of the shop and the field—and the engineer with a thorough technical education.

It was two foremen in the Phoenix shops who, in handling the huge ribs which were to be assembled to form compression chords and posts, became impressed with the flexibility of these members and their unsuitability to act as long compression struts. These criticisms were communicated by the President of the Phoenix Bridge Co. to Mr. Szlapka and Mr. Cooper and were dismissed by them as unsubstantiated.

When the inspectors of the bridge found a bottom-chord member bent—not merely kinked but bent alike in every component part and on its entire length—who was it that perceived the seriousness of the situation? Not the scientifically-trained engineering directors of the work. Birks laughed down all fears. He set his belief that the chord could not be crippling because, forsooth, it was not yet loaded to anything like what it was designed to carry, against the positive statements of observed facts by Clark, Kinloch, Yenser and McLure. Deans, with even less actual information than Birks, asserted that he knew no change had taken place in the member, and over the telephone reassured the staff at the bridge. Szlapka, the man who had designed the bridge, knew every part and how it should behave, saw nothing in the matter to alarm him.

But Yenser, the unschooled erection foreman, realized that the question was one of life and death, and for the time being drew off his men. Kinloch, the bridge inspector, a "practical" man, saw more clearly than any other man the fast coming disaster, and he made a two-days' fight to bring all the others to see the danger. Clark, the yard foreman, another "practical" man, took the same side, and clinched the proof of danger by his declaration that the chord was straight when it left the yard. But all these positive facts and the intuitive perceptions of the men of largest practical experience were over-ridden and silenced by the very men who should have had the best knowledge, the men trained in the scientific analysis of structures and entrusted with responsible charge of the work.

Two men of scientific training, indeed, did appreciate the gravity of the situation. Cooper realized it, although not at all in the way that he would have done had he been on the ground with the failing chords before his eyes; and his realization came too late to save the lives of the workmen. McLure also, who had the advantage of a college training, saw the danger, but, as the man of least experience among those on the ground, he appears to have been least ready to assert his views strongly. And, according to Kinloch, he did not keep his promise to wire if Cooper considered the case alarming. These two exceptions, therefore, do not modify the force of the general statement.

It need hardly be said that we do not draw attention to this matter as an argument against college training for engineers. No man need be one whit less practical as an engineer for a four-years course in an engineering school. The real lesson to be drawn is the lesson of humility. Let us never undervalue the experience of the man who actually handles and works the materials. Better yet, it is the duty of the engineer to be even more practical than the workman. The designer can learn things from the actual machine in the shop that he could never find out from the machine as laid out on the drawing-board. Theory is an absolute necessity; but let us lose no opportunity to check the theories with the behavior of the material in the mill and the structure in the field.

It is of course true that things like this have been said many times before; but the trouble is, we have not taken them to heart. We have supposed that they referred to the men who try to do professional work with nothing but theoretical knowledge. It has not occurred to us that the men in the top ranks of the profession, who have been building great engineering works for nearly a lifetime, needed such admonitions.

And yet that is what the event shows. We all of us, juniors and seniors alike, need to know more,—to test our theories constantly in the light of new knowledge, to welcome such knowledge when it comes, well attested, from any source. Yes, surely, the great lesson of this greatest disaster is the lesson of humility.

LETTERS TO THE EDITOR.

U. S. Civil Service Examinations for Engineers.

Sir: The writer of the letter in Engineering News of March 5 (p. 267), entitled "A Severe Examination for Civil Engineers," should not "kick" until he has taken a look at the examination for the same position published in Engineering News of June 27, 1907.

A man who can get a good mark on these examinations will not have to work for the Government for a salary of $1,200 to $1,500.

The Civil Service Commission will continue to wonder why vacancies in these positions cannot be filled.

New York City, March 10, 1908. Reader.

Partial Explosions of Dynamite Charges.

Sir: Regarding a "Peculiar Accident with Explosives" (p. 285 of this week's Eng. News), I have known of a number of cases of failure to explode all the charges. Once where exploders were supposed to have been made especially for the job (submarine), and repeated failures to explode all the cartridges had been experienced, we tried connecting some 25 exploders, throwing them in the water and firing. The first shot only set off 4 of the 25. The remaining 21 were then reconnected and one shot fired them all. Obviously, the first four to explode were "quicker" than the others.

Yours truly,

T. Kennard Thomson.

Park Row Building, New York, March 13, 1908.

The Collapse of the Bridge Across the Mississinewa at Marion, Ind.

Sir: Accompanying this letter is a photograph of the bridge across the Mississinewa River at this city, one span of which collapsed on March 1, 1908. [See news note in Engineering News, March 12, 1908, p. 290.—Ed.] The bridge consists of two spans, each 160 ft. long and 18 ft. wide, supported on concrete abutments and central pier. It was built and erected in 1904 by the Attica Bridge Co., under the direction of our county engineer, for a contract cost of $24,889. The floor system is very

160-ft. Span of the Collapsed Highway Bridge Over the Mississinewa River.

heavy, consisting of 24-in. floor beams carrying 9-in. I-beam stringers, spaced 2 ft. c. to c. Upturned buckle plates on the lower flanges of the I-beams support a solid concrete floor which extends 15 ins. above the bottom of the I-beams so that, with allowance for the dome of the buckle plates, there is probably an average thickness of 12 ins. of concrete in the floor system.

The abutments and the pier are not damaged in the least, so the high water had nothing whatever to do with the wreck.

It seems to me, from the data at hand, that in order to save the other span from destruction it will be necessary to remove all of the concrete, and use cinder concrete up to the top of the I-beam stringers and cover with creosote blocks. This would relieve the enormous dead load.

Yours truly,

T. E. Petrie, City Engineer.

Marion, Ind., March 14, 1908.

[From the foregoing description it is probable that we were misinformed in our statement of

last week to the effect that the failure was due to undermining of the foundations. Until the flood waters have lowered it will be impossible to make an authoritative statement as to the cause of the collapse, but the evidence would surely seem to warrant condemnation of a floor system so extraordinarily heavy for a country highway bridge.—Ed.]

Subway Car Improvements: The Influence of the Last Car.

Sir: I have just read in your issue of March 5 the interesting article entitled "Types of Rapid Transit Car for Maximum Service" and wish to make some comments upon the problem there discussed. Having to travel to and from my office each day by the subway, I am able to speak from experience.

I would call attention to the fact, which, so far as I can judge, has escaped the attention of the different investigators, that the amount of time consumed by the stoppage of the train at any station is dependent upon the *last* car. This car has only one door available for leaving and entering passengers, and as during the rush hours the rear car is as full as the others, it takes fully twice as long for the passengers to get out as from any other car except the first. Since the door of the last car has to be shut before the first gong can be struck toward the starting signal it holds up the train. While the conditions are the same (as far as the exit of passengers is concerned) in the first car, yet the fact that all the other doors have to be closed before the starting signal reaches the front of the train, makes the conditions for this car much more satisfactory.

On this account there would be no advantage whatever in putting side doors at the center of the cars unless either the station platforms are lengthened or the trains shortened. From my observation I do not think there is any station with a sufficient length of platform to allow the side (center) door of either the first or the last car to be used. Very frequently even the forward door of the last car at the Brooklyn Bridge station is not opposite the platform and all passengers from this car have to pass through the connecting doors and out through the rear door of the car ahead. When this is the case (I have known it to happen two or three times a week) almost three times as many passengers have to pass through this one door as through any other, except the first car, and thus the train is held up for some time by the last car alone. Of course this is due to the inaccuracy of the motorman in stopping the train and can be prevented, but it goes to show how narrow a margin there is now on station platforms, and that even putting additional side doors near each end of the cars as shown in your sketch may do very little good unless the station platforms are lengthened.

Another point that I wish to mention is that the trains are very frequently held for many seconds at stations with no one leaving or entering the doors, the guards keeping them open until they receive the signal to start. This happens almost every morning at 149th St. and Third Ave. station, and frequently at the other express stations.

Yours very truly,

Walter M. Smith, Sr.,
M. Am. Soc. C. E.

1040 Simpson St., New York City, March 7, 1908.

[Mr. Arnold's report recommends automatic electric door signals as a necessary improvement, and he clearly intends such a signal system as well as pneumatic door-operating devices to be put on the altered cars. This change would equalize the condition of front and rear car. These two cars, of course, still remain at a disadvantage, having the doors at one end only available, while all other cars use the doors at both ends.

The question, then, is: Suppose the station platforms were lengthened to cover the full length of front and rear car of the present eight-car train, so as to give all cars the benefit of all their doors; would it then be better to operate the present eight-car trains, or increase the length of the train to nine or ten cars with resulting restoration of the present conditions as to front and rear cars? We incline to the view that, with such lengthening of the station platforms, the longer train would give the greater line capacity, although the station stop might be longer than with the eight-car train on account of the restriction affecting the front and the rear car.

However, our own observation indicates that the front and rear cars do not always, or not generally, determine the length of station stop. A larger number of passengers patronizes the intermediate cars, partly because the station entrances are near the middle of the platform length. As a result the doors of the end cars are often or usually closed before the middle cars have completed their traffic interchange. If this is the prevailing condition, the great expense of putting the end cars in the same condition relative to ingress and egress facilities as the middle cars would not be warranted.

With the addition of a second side door, as recommended by Mr. Arnold, it will, of course, be necessary to lengthen the platforms a trifle so that both doors at front of rear car and at rear of front car can be used. Further, the management should insist strongly on accurate spotting of trains, to avoid delays as reported above from Brooklyn Bridge station, with the resultant reduction in traffic capacity.

As to the delay of trains after the leaving and entering movement is completed, this does not occur in the rush hours, so far as we know, except when the trains ahead are delayed and the signals therefore are against the train. But it occurs very often, at some stations, outside the rush hours, and then it constitutes one of the numerous wonders of operation which remain eternally incomprehensible to the daily subway traveler.—Ed.]

The Field of the Fruhling Dredge.

Sir: As a designer of more than twenty suction dredges, the writer has been much interested in Mr. John Reid's thorough presentation of the "Fruhling Dredge" in your issue of March 5th. There is no issue taken with the facts submitted; but as to the rather sweeping conclusion that the Fruhling dredge will "revolutionize" the suction dredge, there is more to be said, and a few questions are yet in order.

(1) How can a Fruhling dredge cut its own way through shallow waters, marsh, or low upland? (2) How can it clean up along the sides and corners of slips and bulkheads? (3) What would happen to a Fruhling drag-excavator when passing over an old wreck, a rock or a heavy lost anchor? (4) Is it pretended that the thick material handled by the Fruhling dredge could be commercially pumped 11,000 ft. with a 17-ft. lift, as a dredge of the North American Dredging Co. has recently done at Galveston? (5) Is it claimed that this dredge will leave a more even bottom than an ordinary suction dredge radially sweeping its cutter about a vertical spud and having its cutter built as a conical frustum to cut a level bottom?

(6) Is it not known by the advocates of the Fruhling dredge that the ordinary American non-propelling suction dredge can at any time fill its pipes with material of the consistency claimed for the Fruhling dredge? (7) Is it not known by the Fruhling advocates that although possessing this power, we have found that, commercially, we can handle more material to greater distance by limiting the percentage of solids to 15% or 20%? This occurs because: (a) The current runs proportionately faster and about catches up with the sum total in yardage; (b) after issuance from the pipe it does not heap up at the pipe end, but spreads out to a reasonable grade, by the very means of the surplus water. (8) Is it not known by the Fruhling advocates that the propelling hopper-type of dredge has been studiously avoided by our private contractors, because of defects inherent in the type, and which have bankrupted most of those who have undertaken the business? These defects are: (a) The draft is so great that the dredge cannot compete for the vast proportion of shallow dredging in our bays, and inland channels. (b) The first cost is almost prohibitive. (c) The complications of self-propelling craft in connection with maritime laws and certificated officers add much to the expense, without affording special dredging skill.

The writer claims that the above-described inability to work close along bulkheads and in corners of slips, and to accurately clean up limited areas, would alone make the Fruhling dredge commercially inadvisable to the ordinary contractor. Near the end of Mr. Reid's article, the following statement appears:

> A secondary valuable feature of the Fruhling dredge is the method by which the hopper contents can be sucked back through the pumps and discharged on shore through a swiveling deck pipe by means of which a temporary connection to a shore line of pipes can be made. Hitherto hopper dredges have had to dump through the bottom doors.

Is it not known by the Fruhling advocates that the best dredges now working at Galveston, Texas, under the Goodhart & Bates contract, have a simpler and better arrangement for pumping the material ashore, consisting of double drop gates forming between them a suction passage when desired? Here when hopper loads are to be dumped the upper gates are left open, and the lower gates only are in use. When material is to be pumped ashore, both upper and lower gates are kept closed until the dredge is in unloading position. Then the upper gates are slightly opened and a large horizontal gate admits outside water to the channel between the gates, into which is slowly dumped the contents of the hoppers. The writer maintains that this is a much freer and better unloading arrangement than any arrangement of closed pipes.

The writer wishes to be understood as heartily appreciating the improvements shown by the Fruhling dredge in comparison with others of the hopper type, but he would never advise a contracting firm to acquire a Fruhling dredge as a commercial tool, unless many Galvestons need to be filled in by millions of cubic yards of dredgings from fairly deep water, without exact limits.

Very truly yours,

H. S. Wood,
M. Am. Soc. C. E., M. Am. Soc. M. E.

North American Dredging Co., Park Row Bldg., New York City, March 5, 1908.

The Consolidation of New Jersey State Health, Sewerage and Water Commissions.

Sir: In your issue of Jan. 30, you discussed the desirability of consolidating a number of New Jersey Commissions on water supply, flood prevention and sewerage. There has been more or less confusion in the public mind and in the public press in regard to the different commissions, particularly those which have more or less jurisdiction over the Passaic River section of the State, and there will no doubt be an attempt to remove some of the sources of this confusion in the present session of the Legislature. As I understand it, the Potable Water Commission, which was composed of the four Riparian Commissioners and the State Geologist, and which was created for the specific purpose of making a report on the water situation, no longer exists; its report having been filed. The Passaic River Flood District Commission, whose work has been superseded by the State Water-Supply Commission, still exists as a commission, but the salaries of the commissioners ceased on Oct. 23, 1907. The information on which the Governor based his message was evidently at fault with regard to the salaries of the Flood Commission and the salaries of the Potable Water Commission still being a continuing charge on the State. The same confusion has perhaps been created by his reference to these salaries. The work of both of these commissions is now embraced and is being carried on by the State Water-Supply Commission, which, in addition to these duties, is, as you stated in your article, "charged with the collection of revenues for the use of waters appropriated by cities and companies, and is authorized to construct reservoirs for water conservation and flood prevention."

The State Water-Supply Commission finds its work rapidly expanding and has now pending before it several applications for the appropriation of reservoir sites and for permission to construct new or additional water supplies. The Commission is preparing a report [see note appended to this letter] on the relative advantages of the construction of the two reservoirs heretofore proposed on the Passaic drainage area. The Commission has also found that the water question is a pressing one in many parts of this State and is not by any means confined to the Passaic River and its tributaries. The functions of the Commission would seem to be entirely distinct from those that might properly be exercised by the State Board of Health or State Sewerage Commission, and have to do more particularly with the construction and operation part of water supply problems, and since its work and future usefulness will have to do with the entire State it seems proper that its membership should be somewhat scattered throughout the State and represent different sections thereof; particularly as the Commission, at least under the act which created it, must sit as a judicial body to determine the proper distribution, between the several municipalities and companies in the State, of the water drainage areas which should properly be appropriated by each. It would seem that one commissioner could not as satisfactorily determine these matters, as a commission of five might be expected to do.

In regard to the suggestion of reservoir site for Trenton, mentioned in your editorial, it might be proper to say the State Water-Supply Commission was not in any way attempting to interfere with the State Board of Health or with any action that the State Sewerage Commission might take in regard to the purification of the Delaware River water. It, however, seemed to be a proper function of this Commission to point out the possibility of an adequate drainage area and storage reservoir from which a gravity supply might economically be obtained for Trenton, and one which had evidently been overlooked and should certainly be considered in the future development of the water supply of that city. It could hardly be expected that either the State Board of Health or the State Sewerage Commission would find time to take up such a question as this; and, at least in a measure, the justification for a separate commission on this phase of the water question is, by the Trenton situation, made quite evident.

There seems to be no special reason why the Passaic River Flood District Commission should be continued, except that the commission is now in existence and its

members are serving without salaries and expense. There is in existence legislation which was prepared with considerable care, that would provide for flood control on the Passaic River should the scheme for water conservation be abandoned. It would seem, however, that the more feasible procedure would be to combine water conservation and flood control and this will no doubt be done; and when consummated, the work would, of course, be prosecuted under one commission.

The projects for conservation and for flood control on the Passaic River contemplate practically the obtaining of an equivalent yield for water supply purposes, namely, 200,000,000 gals. per day, which might be obtained for an expenditure for reservoir land and construction of $7,500,000. The projects also provide, in addition to the conservation of 200,000,000 gals. of water per day that sufficient water shall be allowed to pass the reservoir to materially increase the low flow of the river. The rapid development of the section of New Jersey adjacent to the Passaic River makes it imperative that some development for water supply purposes on a large scale be undertaken within the near future if economical supplies are to be obtained.

Very truly yours,

M. R. Sherrerd,

Consulting Engineer, State Water-Supply Commission.
Newark, N. J., Feb. 21, 1908.

[Our contention was that the health-protective work of the State of New Jersey could be more efficiently and economically performed by one strong board than by four or five weak ones. Work not of a health-protective character should, of course, not be entrusted to the State Board of Health, unless so intimately connected with the proper work of that board as to make separation difficult without loss of efficiency. The present strong and desirable movement for the conservation, development and utilization of the water resources of our commonwealths, for the benefit of their inhabitants, involves so many industrial and commercial operations, or at least the supervision thereof, that, if carried out as it should be, independent commissions will, as a rule, doubtless be required. Their work and that of State boards of health should be so delimited as regards conservation of the purity of water as to avoid duplication, with its resulting confusion, waste and inefficiency. This would seem to be an easy matter, if approached in the right spirit.

Since Mr. Sherrerd wrote his letter to this journal, the State Water-Supply Commission, we understand, has decided in favor of Mountain View, rather than Little Falls, as a site for a dam to form a storage reservoir for flood prevention and water conservation in the Passaic River drainage area.—Ed.]

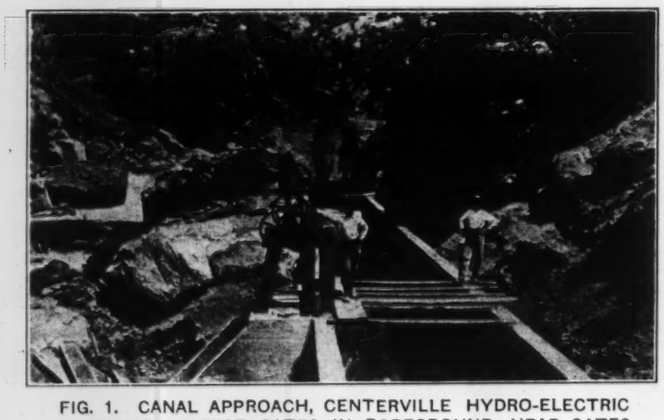

FIG. 1. CANAL APPROACH, CENTERVILLE HYDRO-ELECTRIC PLANT. SLUICE GATES IN FOREGROUND; HEAD GATES AND DAM IN BACKGROUND.

Notes and Queries.

H. E. E., of Houston, Texas, asks what methods are currently employed in large bridge and structural shops for centering columns on the milling machine for facing the ends square. The question is referred to our readers.

W. C. K. asks some of our readers to give their opinions as to the proper value of the coefficient "n" in Kutter's formula, applicable to the flow of water through corrugated sheet iron pipes. This pipe, our correspondent states, is being largely used in the West, due to its low cost, and he is of the opinion that friction in it will be high, on account of the corrugations.

A correspondent is of the opinion that our answer to a letter of inquiry as to driven wells as a source of water supply, in our issue of Feb. 28, 1908, showed a lack of understanding of the point of view of the questioner. The letter of Mr. Bowers in our issue of March 5, our correspondent thinks, confirms this opinion. Our present correspondent states that while in the South some months ago he heard a good deal about wells being sunk in sand-bars in the Ohio River. These wells are claimed to be natural filters and have been patented by Mr. S. Smith, Manager of the Kanawha Hotel, Charleston, W. Va. It is claimed that by sinking such wells a naturally filtered water is obtained, doing away with the filters that would be required if water was taken from the Ohio River. The promoters of such wells urge the economy and efficiency of their system and where sand-bars are not available they claim that they can be made to order, and wells sunk, with good results. Our correspondent states that strong reports have been "written by engineers in favor of the natural sand filters in river beds" and "equally strong reports against them by men who possess some knowledge of filters"; also that "the majority of physicians seem to favor the sand-bar wells as against mechanical filters."

As we stated in our issue of Feb. 20, it is generally safer to consider wells sunk in river or lake beds *as wells* rather than as filters. Without careful studies, no one can tell how much of the water drawn from such wells is river water and how much is ground water that may have passed through the ground for a long distance. It does not follow that because water from a well driven in a river sand-bar contains 0.5% as many bacteria as the river water over and immediately surrounding the bar, that the well has removed 99.5% of the bacteria in the river water. And the same holds good as to turbidity. Where a city is contemplating a new water supply the only safe course for it to pursue is to employ a competent engineer, not financially interested in any contract scheme, and then follow his advice as to which is the best and cheapest of the various available sources of supply. To take the mere say-so of either, a driven well contractor on the one hand, or a filter manufacturer on the other, is like dispensing with the services of a physician and being guided solely by the advice of the manufacturer or selling agent of some cure-all drug or compound. In saying this, we intend no reflection on contractors or manufacturers. It is their business to sell their services or their wares. But it is the business of the municipalities, whether providing water or any other municipal necessity to choose the best available method or apparatus to effect the work in hand. This can be done only by securing and following the advice of some one possessed of a knowledge of all the means by which the desired results may be accomplished, competent to judge which of those means is best adapted to local conditions; and, moreover, some one not financially interested in any of the methods from which the choice is to be made.

Mr. Quincy Tucker, 181 Lincoln St., Boston, writes us that the average variation between high and low water level on the Madeira River in Brazil, at San Antonio, is 44½ ft. and not 80 ft., as stated by Mr. Ernest H. Liebel in our issue of Oct. 24 last. Mr. Tucker, in exploring the river in 1905, found September to be the month of lowest water. The least rainfall was in July, about 0.16 in., and in January, 14.67 ins. fell.

MUNICIPAL SANITATION IN CUBA has been taken over by the general government in accordance with a decree signed Aug. 26, 1907. The decree is summarized by Dr. F. H. Slack, Assistant Director, Boston Board of Health Laboratory, in the "American Journal of Public Hygiene" for February, 1908, as follows.

(1) The abolition of the municipal boards of health, and the transfer of all powers previously vested in them to a national official, the local sanitary officer, who is appointed by the highest executive authority.

(2) The assumption by the State of the cost of all municipal sanitary works and services, with the proviso that the municipal governments shall refund to the State, in consideration thereof, one-tenth of their total incomes for each year.

(3) An increase in the powers of the chief sanitary officer, who is made, in fact, the administrative authority of the department. The Superior Sanitary Board is at the same time reduced in number and authority, a majority of its members being members ex-officio of the National Sanitary Board. The role of the new National Sanitary Board will be rather advisory than administrative.

THE HIGHEST HEAD FRANCIS TURBINE: C[ENTER]VILLE HYDRO-ELECTRIC POWER INSTALLATI[ON] OF THE CALIFORNIA GAS AND ELECTRIC CORP[ORA]TION.*

By JAMES H. WISE,† Assoc. M. Am. Soc. C. E.

There has been in successful operation for [a] period of three months a turbine installation which [is] of considerable interest and importance, it being [a]s writing, to the writer's knowledge, the highest [Francis] turbine in the world. Because of the radical departure from ordinary turbine practice it is thought [that] a brief description of the plant would be of interest to those engaged in the design and construction of hydro-electric installations.

THE CENTERVILLE POWER PLANT.—The Centerville Power Plant is situated on Butte Creek, in the northern part of California, thirteen miles northeast of the town of Chico, and is one of eleven plants belonging to the California Gas and Electric Corporation, which furnishes most of the electric power for the central and north central part of California, but chiefly for San Francisco and the bay cities.

Briefly stated, the Centerville power plant consists of one 900-KW. impulse wheel unit, under a static head of 577 ft. from headwater surface to center of nozzle, and this Francis turbine, under a total head 591 ft. from the surface of the head water to normal tail water. Under an effective head of 565 ft. it has a rated capacity of 9,700 HP. It is direct connected to a 5,500-KW. generator.

These units are supplied with water by three pipe lines, 2,566 ft. long, which are in turn supplied from Butte Creek by a canal 8.3 mi. long. Beginning at the head works of the canal, the installation will be more fully described as follows:

HEAD WORKS.—The intake of the canal is on Butte Creek, about one-fourth of a mile below the de Sabla power house, which was fully described by Mr. J. D. Galloway, M. Am. Soc. C. E., in Engineering News.

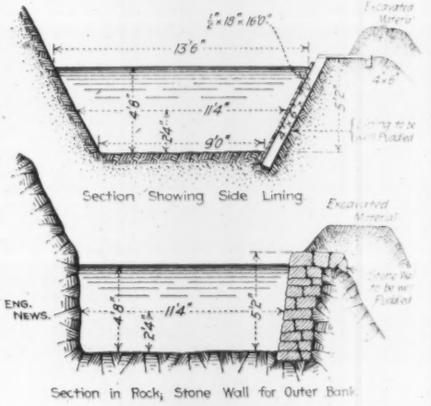

Fig. 2. Typical Sections Through Canal Ditch; Centerville Hydro-Electric Plant, California Gas and Electric Corporation.

Aug. 10, 1905. Centerville, therefore, makes use of the water a second time, the first drop at de Sabla being 1,531 ft., where a total capacity of 14,000 KW. is installed. Diversion is secured by means of a cyclopean concrete dam, 15 ft. high, 3 ft. wide on the crest, 90 ft. long and arched up stream. During construction, an old log crib dam up stream from the new dam site was made use of as a wing dam and excavation to solid bed rock was easily effected. Forms were constructed, and the concrete, a 1-2½-5 mixture was wheeled and dumped into place. Large clean boulders, one and two man size, were placed sporadically throughout the mass and as much large rock was used as possible, care being taken, however, to keep the pieces placed by hand, at least three or four inches apart, and the same distance from the forms. The concrete was poured wet, and each large rock was worked into place to secure a good bed. Spalls were also used wherever space between the large rock permitted. The crest of the dam was finally finished off with rich grout, giving a smooth hard surface.

The flow of water into the head of the canal is regulated by means of two heavy wooden gates, each operated by means of a mechanism similar to the one used for operating the side gates shown in Fig. 1. A concrete wall supports the gates, and elevates the operating device above extreme high water. It also answers as a protection to the canal approach at times when Butte

*A paper read at the bi-monthly meeting of the San Francisco Association of the American Society of Civil Engineers, Feb. 21, 1908.

†Assistant Engineer, California Gas and Electric Corporation, San Francisco, Cal.

Creek is running high, and carrying large quantities of debris. One feature of the canal approach is that the bottom has a rapid grade from the head gates to the side gates, a distance of about 100 ft., at which point it is 4 ft. below the canal grade, thus allowing the sand and gravel to settle and be discharged through the side gate at intervals, depending upon the rapidity with which it collects. The 4-ft. rise from the bottom of the approach to canal grade is vertical, and curved from the back wall to the lower side of the gate, as seen in the foreground of Fig. 1. This prevents turbulence, or

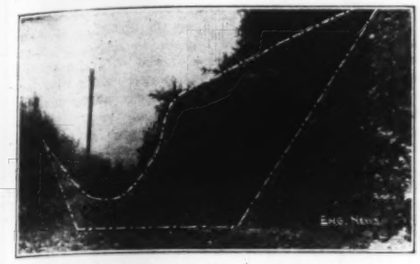

Fig. 3. Old Mining Ditch Reconstructed for Centerville Hydro-Electric Plant.
(Dotted line shows comparative cross-sections of old and new ditches.)

boiling, and the velocity of approach is made effective for discharging the sand and gravel through the sluice gates.

CANAL.—The canal as previously stated is 8.3 mi. long and consists of 1.6 mi. of flume and 6.7 mi. of ditch. It was originally a mining ditch with a capacity of 45 sec. ft., and dug on a uniform grade of 1.28 ft. per 1,000 ft., except 2,000 ft. at the upper end, where this is increased to 2.6. As reconstructed, the canal has a capacity of 175 sec. ft. and of course has the same grade. The different ditch sections used are shown in Fig. 2. The side slopes were not specified, but were determined in the field, the construction depending upon the character of the material encountered. Plank side lining was used only where the outer bank was porous, and no rock was convenient for rock wall work. If rock was plentiful, a wall was constructed as shown. In the case of either plank lining, or rock wall work, clay puddle was placed between the berm and the

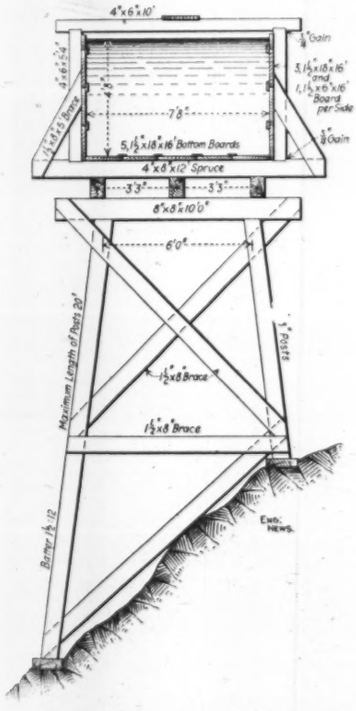

Fig. 4. Flume Section, Centerville Hydro-Electric Plant.

lining to prevent the saturation and sloughing of the outer bank. Either method of lining was resorted to only where the berm was loose and porous. Fig. 3 is a photograph showing the original and final section of the ditch, and at this particular place presents a working face of 110 sq. ft. or 4 cu. yds. per lineal ft.

The flume work was constructed as shown in Fig. 4. The battens and 1½-in. boards, or so-called box boards, are of heart sugar-pine throughout, while the belting, stringers, and bent work are of heart spruce. All material is native. The framing was done at the head of the canal, and the lumber floated down and distributed before actual construction commenced. The ditch and flume work was then carried on simultaneously. To expedite the framing, a 6-in. Fox dado head, and 16-in. cut-off saw was installed and run by an electric motor. The dado would cut a gain ¾ in. deep and 6 ins. wide very quickly and much cleaner and better than could be done by hand. The flume footings were prepared by excavating to a solid foundation and 6 × 8-in. cedar blocks were used as mud sills, upon which were placed the batter posts. The cedar resists decay better than the spruce, and is easily renewed.

In constructing the flumes, care was taken to have at least 16 ft. on either end of the flume constructed on the ditch tangent throwing all of the curve into the flume proper. This eliminated the disturbance at the ends of the flumes which was still further guarded against by goring the end boxes and finishing off with about 4 ft. of rock wall with a warped surface. This is clearly shown in Fig. 5. These precautions practically eliminate entrance and exit losses. Deep sand boxes with waste gates were placed at intervals along the canal, and serve the dual purpose of catching silt, and for turning the water out of the canal in case of trouble from slides, or other causes. At the lower end of the canal, about 300 ft. above the forebay, a large settling basin was formed with deep waste gates. Two sets of flash boards, 10 ft. wide and 2 ft. high were also provided, which arrangement is shown in section and elevation in Fig. 6. A grizzly was placed in the canal just above the basin, at an angle of 30° with the horizontal and the submerged end was supported by a heavy angle 1 ft. above the bottom of the ditch. This allowed any heavy material, such as sand and fine gravel to pass under the grizzly and into the settling basin. The 30° slope allows the limbs, leaves, etc., to be carried up on to the grizzly by the velocity of the water. The grills are occasionally cleared by an attendant, who also patrols the canal daily, keeping it in repair, and free from weeds, etc. The flash boards are automatic, i. e., they trip if the water raises above normal, and return to the vertical position when the water drops below normal. This arrangement eliminates the construction of a very wide crested shallow weir, and permits of close regulation of the head water level.

FIG 5. WARPED SURFACE TRANSITION FROM CANAL TO FLUME.

The steep side hill slopes at the lower end of the canal made a regulating reservoir at the head of the pipes impracticable. A reinforced-concrete forebay was therefore constructed. This forebay, Fig. 7, is 25 × 18 ft. in plan, 20 ft. deep with 6-in. walls and with counterforts properly spaced. Round rods were used for reinforcement. Two vertical walls separate the three pipe intakes, which with a proper arrangement of gates, permit any one of the pipes to be emptied while the other two are in operation.

PIPE LINES.—It should be here explained that the original Centerville plant was put in operation in December, 1902, and the installation at the time the Francis turbine was first considered consisted of two 400-KW. units and one 900-KW. unit, "all impulse wheels. Two 24-in. pipe lines supplied the water under a static head of 577 ft. The new installation necessitated the removal of the two 400-KW. units. The 5,500-KW. turbine unit was then installed, and occupies the same floor space. A third pipe line 36 and 42 ins. in diameter was also included in the new installation, the three pipes being connected together at the power-house by means of a multiple casting, shown in Fig. 8, a "T" being placed in one of the 24-in. pipes for the 900-KW. water wheel connection. The new line is of riveted steel, 2,566 ft. long, of which 675 ft. is 36 ins. in diameter, and 1,891 ft. is 42 ins. in diameter. The pipe is made up of cylindrical outside and inside courses, and the diameters given are the inside diameters of the inside courses. The longitudinal seams are double riveted lap joints of about 70% efficiency; the transverse seams are single riveted. A slip joint is provided near the forebay which allows of expansion and contraction of the pipe line. The pipe was furnished and laid by Schaw, Batcher & Co., of Sacramento. It was fabricated in their shops in three course sections 23 ft. in length, shipped to Chico by rail, and hauled to Centerville on wagons. Pneumatic tools were used for all field work, such as reaming, riveting, calking and holding on. The pipe is supported on concrete piers at intervals, and securely anchored with 1¼-in. round iron rods. Six-inch air valves were placed at the critical points.

POWER-HOUSE.—The original power-house erected in 1902 was made use of to the extent that the concrete walls were raised, and substantial steel roof trusses were substituted for the original wooden ones. A crane runway was erected for nearly the entire length of the building, carrying a Cyclops hand operated crane of 60,000 lbs. capacity. In one end of the building is situated the transformer room, while the other end is provided with a well equipped machine shop. The building is fireproof, and rests on a solid sandstone formation.

TURBINE.—The turbine is of the radial inward flow, single axial discharge, Francis type, with a horizontal shaft. It is connected by means of a 45-in. gate and taper piece to the "Y" casting which is the confluence of the three pipe lines previously mentioned. At full load it operates under an effective head of 565 ft. and has a speed of 400 r.p.m. The rated capacity is 9,700 HP., but the wheel has never exceeded 8,200 HP., due to the limited capacity of the generator. It has a cast steel spiral casing, made in two parts, and provided with a quarter turn discharge to the draft tube and a pressure regulator. The runner, Fig. 9, is of cast steel, with 20 vanes; 24 pivoted guide vanes are provided, and are connected to a shifting ring, which is in turn connected to the governor rocker shaft by lever arms as shown in Fig. 11. A thrust bearing of cantilever type takes up the end thrust which arises with sudden changes of load, and is supplied with oil under pressure. A ring oiling bearing of the ordinary pedestal type on the discharge side of the wheel supports the other end of the shaft. The discharge pipe is bolted to the riveted steel draft tube which leads to the concrete lined tunnel as shown in the general section, Fig. 12.

This figure also shows the location of the pressure regulator, or relief valve, which is governor operated and is designed to relieve the pipe line and wheel casing of excessive pressure and water hammer when the vanes are closed. If the guide vanes are suddenly closed, the pressure regulator discharge is opened, but has the general tendency to close, and does so gradually through the agency of a relay valve and dashpot arrangement. If the vanes are closed slowly, the regulator does not operate. The dashpot can be cut out, and the pressure regulator will then act as a by-pass, being closed when the vanes are open, and vice versa. Tests were made of the relief valve at the time the turbine was first put in operation. The machine was running at full load, or discharging about 155 sec. ft., the vanes were suddenly closed, the relief valve opened at the same time, and closed after a period of 30 sec. The total rise in pressure was 15 lbs. above the static, or 28 lbs. above the working pressure. With conditions at 1,000 KW. load, the time of closing was 5 sec., and the rise in pressure above static was 41 lbs., or 42 lbs. above the working pressure. The guide vanes and relief valve are operated by a type N Lombard governor, which is connected to the rocker shaft by suitable pinions and segment, the relief valve being lever-connected to the bell crank of the shifting-ring lever.

With this type of wheel it is necessary to have a load limiting device for regulating the gate opening, for if additional load comes on the system, the governor would ordinarily open the guide vanes, and might do so to such an extent that more water would be used than the canal at that time may be furnishing, or the generator may become overloaded, for as above stated, the capacity of the turbine is considerable in excess of that of the generator. For this purpose a load limiting device was instituted by Mr. J. P. Jollyman, Superintendent of Electrical Construction, which is an adjustable connection between the valve stem pinion and the rocker shaft of the anti-racing mechanism on the governor. This device works admirably and enables the operator to adjust the governor so that the wheel will not exceed any de-

FIG. 7. REINFORCED-CONCRETE FOREBAY, CENTERVILLE HYDRO-ELECTRIC POWER PLANT.

sired load. The governor oil-pump is a triplex 4 × 6-in. type, run by a 7.5-HP. induction motor.

The turbine was furnished by the Allis-Chalmers Company of Milwaukee, and was designed by Mr. Arnold Pfau. It was through the efforts of Mr. F. G. Baum, formerly Chief Engineer of the California Gas and Electric Corporation, that this departure from the customary turbine practice was made.

The generator is a 5,500-KW., 3-phase, 60-cycle, 2,400-volt, 400-r. p. m. machine, furnished by the Stanley G. I. Electric Mfg. Company. It is supported on a 16-in. shaft between two oil-ring bearings. The generator and water wheel shafts are connected by a bolted-flange coupling. Excitation is secured from a water-wheel motor exciter set of 60 KW. capacity.

Six 840-KW., and three 360-KW. shell-type, water-cooled transformers complete the main features of the installation. The circulating water for the transformers is used under a 50-ft. head, and is piped from a reinforced-concrete tank, 10 ft. in diameter, and 6 ft. deep, with 4-in. walls. Clinton wire fabric was used for reinforcement, and the tank was absolutely water tight without the use of any water-proofing material.

The high tension lines (60,000 volts) are led from the transformer room out of the end of the building to a reinforced-concrete fireproof switch house provided with "Baum" high tension switches and open air switches, for cutting on or off the de Sabla lines The switches are lever controlled from the switch board.

Mr. J. P. Jollyman, Superintendent of Electrical Construction, under the direction of Mr. C. F. Adams, Assistant Electrical Engineer, had charge of the electrical installation, and the hydraulic and civil engineering work was carried on under the direction of the writer.

USE OF HIGH-HEAD FRANCIS TURBINES.—Before closing the writer will endeavor to show the field to which the so-called high-head turbine is best fitted. For the past few years the general tendency has been on large systems to install electrical units of large capacity and high speed for the sake of economy in first cost, operation and maintenance. Impulse wheels are adapted to such installations with pressure heads of say 800 ft. and upwards (the writer has reference to units of 5,000 KW. and over and not of less than 300 r.p.m.) but for low heads, or for medium heads, say in the neighborhood of 300 to 600 ft., the turbine is better fitted for large units as can be shown by comparison, taking the installation just described.

The quantity of water used is approximately 155 sec. ft. If impulse wheels were used, there would be required two wheels with nozzles about 9 ins. in diameter, or three wheels with about 7¼-in. nozzles. The latter would be allowable, but a speed of 400 r. p. m. would be entirely out of the question, for with that speed, a pitch diameter of about 4 ft. would be necessary (considering the speed of the pitch circle as 64% of the spouting velocity). That means that the disk would have a diameter of say 3 ft.; the buckets on the other hand would have to be about 18 ins. in width, and such a combination of large buckets on a small disk would be mechanically poor and inefficient.

With the 300-r.p.m. machine, the pitch circle would be a little over 5 ft., with a disk diameter of about 4 ft., but with the same size buckets, which is still an undesirable arrangement. We may arrive at the conclusion then, that at least three impulse wheels would be necessary and that the speed of the machine must be about 250 r.p.m. There would result therefore three wheels instead of one, and a more expensive generator. With the Francis turbine, on the other hand, only a single wheel is necessary and if desirable the speed could be increased to about 500 r.p.m. Also generators of larger capacity than 5,500 KW. could be used.

Furthermore, we should not lose sight of the fact that by means of a draft tube, the turbine can gain additional head over that of the impulse wheel, for in the installation just cited, the impulse static head is 577 ft. against the total head on the turbine of 591 ft., an increase of about 2.4%, which means 2.4% more power for the same quantity of water.

The following extracts from the discussion* on Mr. Wise's paper by Mr. H. Homberger, an engineer of the Abner Doble Co., San Francisco, Cal., presents some interesting opinions from the impulse-wheel maker's point of view on the Francis type as a competitor to the other class:

Whether under certain given conditions, viz., head, character of load, length of pipe line, and velocity of flow in the latter, an impulse wheel or a turbine is more advantageous, is at present still an open question. In Europe, low-head plants are installed in preference to high-head developments, because in thickly settled countries it is difficult and costly to acquire high-head water rights, which, to a large extent, holds true in the northeastern part of the United States. Therefore, the low-head water-power machine in Europe has reached a higher state of perfection, and designers and users are more in favor of it because more familiar with that type of hydraulic prime mover. On the Pacific coast, where high-head water powers can be obtained easily and cheaply, where the water supply is limited, and where the transportation of great bulk is expensive, high-head installations are preferable; and with the exacting requirements of hydro-electric power generation and transmission, the crude and inefficient hurdy-gurdy of the early miners has, in the form of the modern tangential water-wheel, reached a very high point of perfection.

The most important points, and at the same time the most delicate, with any water-power machine are efficiency and regulation; and in order to pass upon a certain machine as a new departure and eminently successful, these points deserve first consideration. Definite efficiency tests have not been made on the Centerville turbine, but Mr. Wise states that the efficiency will be above 80%, as indicated by preliminary tests. This is nothing extraordinary, as 83% efficiency can be obtained easily with impulse wheels under the conditions as stated. The guaranteed efficiencies were 80% at full load, 82% at three-quarter load, and 77% at half load. If the turbine should run under a heavily fluctuating load, the average efficiency must be decidedly lower, as Mr. Wise stated, with a closing time of 5 sec., that it took the relief valve 30 sec. to close. The relief valve having the same vent as the turbine, this must necessarily result in a considerable waste of water.

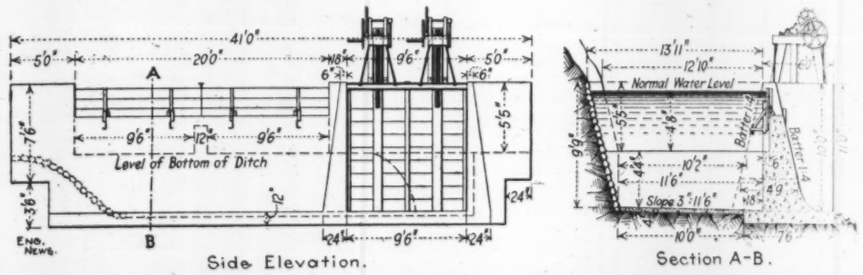

FIG. 6. SETTLING BASIN IN CANAL OF CENTERVILLE HYDRO-ELECTRIC POWER PLANT.

Fortunately for the turbine, such conditions do not exist in the Centerville plant. The turbine is expected to run under full load all the time, and the regulation is taken care of in some other plant by impulse wheels, where a storage reservoir is available, and, incidentally, where the most efficient operators are located.

For this reason, probably, Mr. Wise has not dwelt on the regulation performance of the turbine; the relief valve apparently was tested as a safety device only, and not as one of the elements of the regulating and governing mechanism. It was evidently satisfactory to see that no trouble occurred when the entire load was dropped suddenly. With a frequently and heavily varying load, and a velocity of some 12 ft. per sec. in the supply pipes, as the conditions actually are

*Reprinted from the "Journal of Electricity, Power and Gas, March 7, 1908.

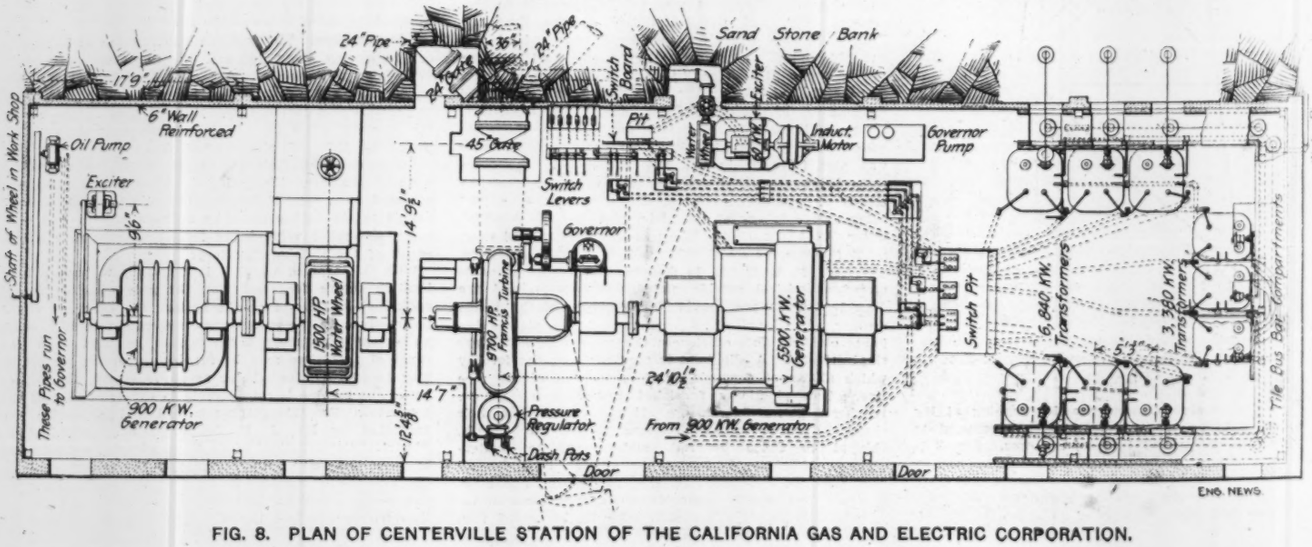

FIG. 8. PLAN OF CENTERVILLE STATION OF THE CALIFORNIA GAS AND ELECTRIC CORPORATION.

at Centerville, no satisfactory regulation could possibly be obtained with this turbine.

Mr. Wise stated that for large units under heads from 200 to 600 ft., a Francis turbine was cheaper than an impulse wheel, a higher turning speed could be obtained, and the application of a draft tube resulted in a better utilization of the available head. I wish to somewhat modify these statements.

The purchase price alone of the bare turbine is no criterion of the ultimate expense to the user. Sales prices are not always governed entirely by the actual manufacturing cost of a machine. In order to give good regulation for varying loads, the pipe line must

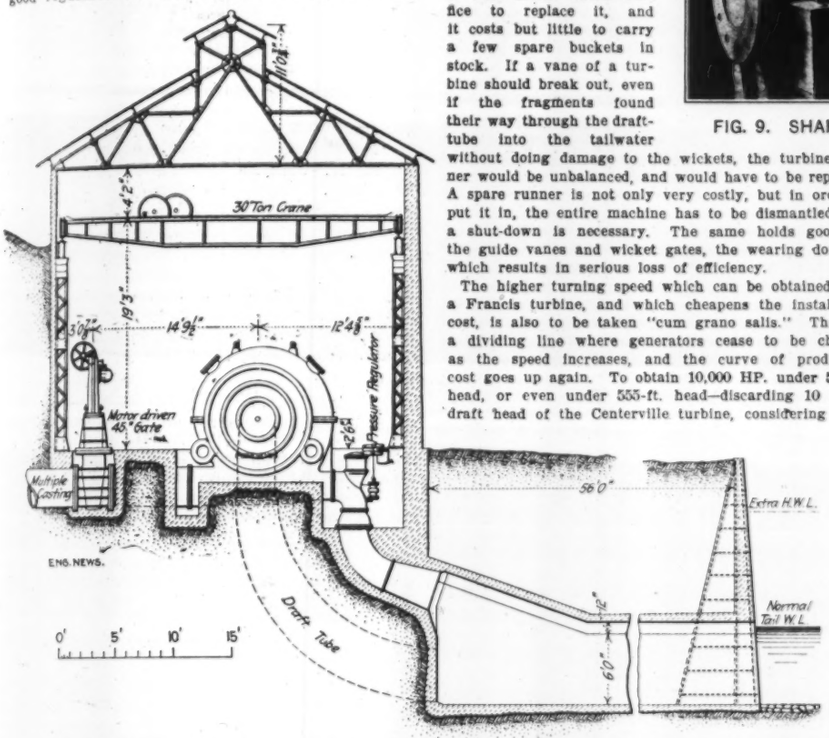

FIG. 12. SECTION THROUGH CENTERVILLE STATION OF THE CALIFORNIA GAS AND ELECTRIC CORPORATION.

be considerably larger in diameter for a turbine than for an impulse wheel under equal conditions; and last, but not least, the maintenance expense must not be overlooked. This turbine has been running less than four months, and under extremely favorable load conditions, but the elaborate protections necessary to guard the turbine against wear of the working parts permit a direct conclusion as to how undesirable the replacing of these parts would be. With an impulse wheel, the only wear, even if the water is carrying much detritus, occurs at the nozzle tip, needle, and buckets, and the latter suffer very little, as experience has shown. The replacing of these parts is very simple and quickly accomplished. Should by accident a bucket break, a few hours would suffice to replace it, and it costs but little to carry a few spare buckets in stock. If a vane of a turbine should break out, even if the fragments found their way through the draft-tube into the tailwater without doing damage to the wickets, the turbine runner would be unbalanced, and would have to be replaced. A spare runner is not only very costly, but in order to put it in, the entire machine has to be dismantled, and a shut-down is necessary. The same holds good for the guide vanes and wicket gates, the wearing down of which results in serious loss of efficiency.

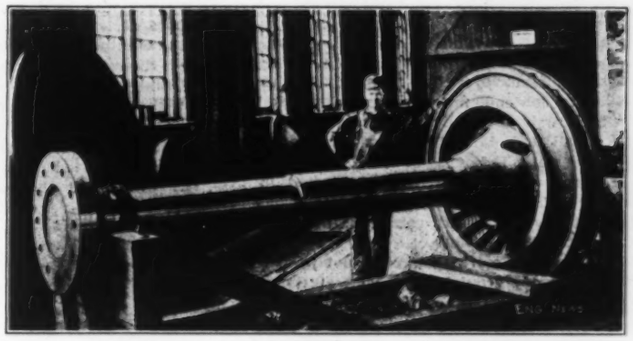

FIG. 9. SHAFT AND RUNNER OF 9,700-HP. FRANCIS TURBINE.

The higher turning speed which can be obtained with a Francis turbine, and which cheapens the installation cost, is also to be taken "cum grano salis." There is a dividing line where generators cease to be cheaper as the speed increases, and the curve of production cost goes up again. To obtain 10,000 HP. under 565-ft. head, or even under 555-ft. head—discarding 10 ft. of draft head of the Centerville turbine, considering these 10 ft. the difference between highest and lowest tailwatel level—a speed of 400 r. p. m. could be readily obtained without putting several wheels on the shaft or using two or three nozzles to each wheel. With the most modern design of vertical-shaft, multiple-jet impulse wheel, turning speeds can be obtained which give all that can be desired in low cost of first installation, and the high-pressure step bearings, which seemed to be objectionable, have successfully passed the experimental stage. Such units of large capacities have been successfully installed in Mexico and Brazil by the manufacturer who is in reality responsible for the Centerville turbine. Under 550-ft. head, such vertical units would not take a bit more room in the power-house than a horizontal or vertical Francis turbine. This, however, was of secondary importance at Centerville, as the power-house was already provided, and only height had to be added.

Draft tubes are no monopoly of the turbine. They can be used as diffusers for impulse wheels also. It is the question, however, whether it pays to go to the trouble, loss, and expense caused by stuffing boxes, air-tight housings and foundations, to gain 1% or 2% in power, which is only actually gained during the period of low tailwater, and which is materially cut down with fractional loads. If it can be shown that an impulse wheel under a 555-ft. head gives a 3% better efficiency than a turbine with 10 ft. additional draft head, then the advantage of the draft-tube claimed for the turbine is offset.

In summing up, I wish to say that to justly compare the two types of machines, two cases must be selected where both work under the same conditions—all details and service conditions must be considered—and I believe I am safe in saying that under a 600-ft. head, and even for 10,000 HP., the impulse wheel is today the more satisfactory machine, if properly designed and built. To draw the conclusion from this particular turbine, with the easy conditions of load and regulation under which it has been working for four months, that a 10,000-HP. reaction turbine is more desirable than an impulse wheel under a 600-ft. head, I should at least call premature.

A NEW FOREST RESERVATION in the Ozark Mountains of Arkansas containing 920,000 acres has been created by President Roosevelt. The new forest brings the total area of the national forests in the United States up to 164,963,555 acres, practically all situated in the Rocky Mountains and Pacific coast region, and all of it west of the Mississippi River.

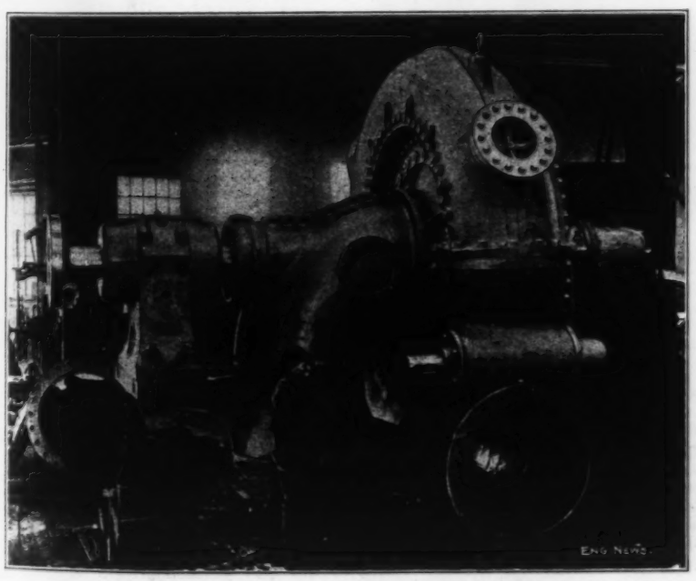

Fig. 10.

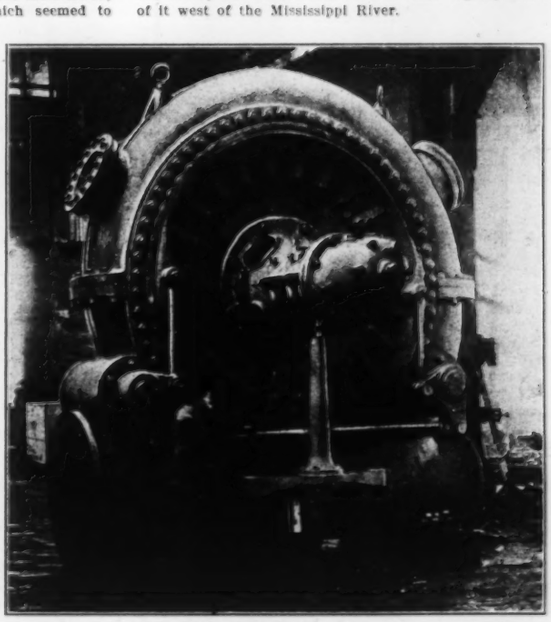

Fig. 11.

FIGS. 10 AND 11. TWO VIEWS OF 9,700-HP. FRANCIS TURBINE MADE FOR CALIFORNIA GAS AND ELECTRIC CORPORATION BY THE ALLIS-CHALMERS CO.

SOME USEFUL TOOLS FOR SURVEYORS WORKING ALONE.

By THALEON BLAKE, C. E.*

The land surveyor has many difficulties with which to contend, not the least of which is the lack of assistants. Usually the surveyor's fees are small and do not warrant a full quota of chainmen and rodmen. Several devices are here presented which the writer has tested in field practice. They are simple but practical and useful and any blacksmith can make them at small expense.

The common marking pins do not push readily into hard, dry ground. For some stations, especially the terminals, a marking pin which can be driven into any ground without danger of injury is very desirable. Fig. 1 shows a pin made out of an iron rod of size to withstand axe blows, to which a small ring is soldered, or welded. This ring is conveniently used to fasten the red silk or cloth which assists in finding the pin in grass; the ring also allows the pins to be strung on a wire or cord for convenience in carrying them. The ring is fastened to the side of the rod, thus leaving the top of the rod exposed to the blows of the axe if it is necessary to drive it into extremely hard ground. But this exposed flat top serves another purpose equally important. When the pin is set plumb, a rod may be centered on its surface as often as the station's bearing may be needed as the field operations proceed. Any surveyor who tries these pins once will never allow himself to be without a few of them.

On street pavements it is frequently important to have a pole stand upright without a rodman to attend it. Figs. 2, 3 and 4 show devices which should appeal to most surveyors as being satisfactory substitutes for human supports. Fig. 2 is rather cumbersome, unless made light for short and slender rods. Fig. 3 is a most useful pole support, paying for its cost many times over if much work has to be done in city suburbs where the distance between stations is considerable. The wind that this pole and attachment cannot stand against is far too strong for accurate transit work. Fig. 4 is not a pole at all, but a "cane style" music stand adapted to take a pole's place where a short signal will do. A music stand of this type is light and portable. A small plumb very materially adds to the accuracy and value of this adaptation. A sliding extension may be applied to one leg for ease of adjustment, as shown.

If a surveyor wishes to have a very complete stock of home-made implements, Fig. 5 will, perhaps, give him a "three-in-one" tool. It may be used as a very large pin; its offset makes a place for hammering it down into a hard road or pike, as well as a support for a small pole which the ring at the top keeps upright; besides these, the tool will take the place of a very little pole, sufficient to project over high grass, provided the upper portion which terminates in the ring is turned so as to be on line. It is more of a novelty than anything else, yet some surveyors who have copied this pin and pole support declare that one or two in a kit of tools come into practice oftener than men who boast of their own resourcefulness would suppose.

Many a surveyor, on arriving at a corner-stone, wishes that there were a hole in it into which he could slide a pole. In town and city monuments there is no reason why a gas pipe should not be inserted for the purpose of holding poles, if water and the danger of freezing could be eliminated. Figs. 6 and 7 depict the essential features of monuments which will support a pole.

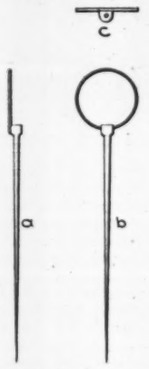

Fig. 1. A Substantial Marking Pin.

Fig. 6 shows a piece of apparatus which may be used as a property line marker, where there are wide sidewalks, or it may be set in paved streets. If set in grass, it should be low enough to miss a lawn mower and to escape the prying eyes of boys who otherwise might be impelled to investigate what the mysterious hole might contain. Fig. 7 shows a durable monument of concrete molded around an iron tube pole-supporter. With drainage vents and an iron cover it excels the old style stone type of monument.

In short, numerous as are the implements displayed in catalogs of supplies, there exists no civil engineer of varied experience who has not felt a need for new devices, or variations of the old. Many times these are only pet inventions, dear to the heart of the inventor, which fail to captivate others, yet, now and then, real improvements are originated which lighten the burdens of these true servants of the people—the civil engineers and surveyors who are unknown to fame.

*Sidney, Ohio.

NOTES FROM ENGINEERING SCHOOLS.

UNIVERSITY OF CALIFORNIA.—In 1906 Mr. Clarence H. Mackay, jointly with his mother, Mrs. John W. Mackay, gave the University of California $100,000 for the endowment of a Professorship of Electrical Engineering in memory of John W. Mackay, Jr. In accordance with a provision that the income from this fund, over and above the salary of the incumbent of the chair, was to be used for furthering research work in electrical engineering, the regents of the university have recently established two "John W. Mackay, Jr., Fellowships in Electrical Engineering." These fellowships have an annual value of $600 each and are open to all properly qualified university graduates. Each appointment is to be for one year but the appointments may be renewed at the discretion of the Graduate Council of the University. The place of residence of those holding these fellowships is to be at the University of California.

UNIVERSITY OF MICHIGAN.—At the January meeting of the Regents of the University of Michigan, architects were authorized to draw up detailed plans and specifications for a new chemistry building, of three stories and a basement, to be 270 ft. long and 150 ft. wide. It will be of brick with stone trimmings and with the interior of reinforced construction. There are to be two interior courts separated by a narrow section connecting opposite sides of the building. The cost is estimated at $275,000. It is expected that construction can be started in May, 1908, and completed by October, 1909.

It is planned to provide facilities for twice the present amount of instruction in chemistry. The building will include two large laboratories for general chemistry, two large laboratories for qualitative analysis, one for advanced general chemistry, one for beginning quantitative analysis, one for advanced quantitative analysis, one for beginning organic chemistry and one for pharmaceutical chemistry, with smaller laboratories for advanced and special work, as well as offices and private laboratories for the instructing staff. There will be one large amphitheater which will seat 350, and three smaller lecture rooms to seat 220, 160 and 100 students respectively. Seven small rooms will be used for recitations. The library, in which a large proportion of the chemistry books are to be kept, will be in charge of an assistant librarian. The pharmacy museum will be placed on the third floor and the museum of chemical technology on the second. The narrow section between the courts contains the supply and dispensary rooms.

FIRE DESTROYED THE COKE WASHER, tipple engine house and laboratory of the plant of the Colorado Fuel and Iron Co., at Sopris, Colo., on March 15, causing $150,000 damage and making 300 men idle.

THE RIGHT TO FIX STREET RAILWAY FARES in a franchise has been affirmed by the Public Service Commission of the Second District of New York State, in response to a petition by Elvin N. Edwards against the New York & Long Island Traction Co. The predecessor of this company was granted a franchise by the Commissioners of Highways of the town of Hempstead, N. Y. The franchise provided for a maximum fare of 10 cts. for a ride over the entire line of the company (about eleven miles), and of 5 cts. for any single continuous ride of five miles or less. The company has been charging 10 cts. for a ride between a point in the village of Freeport and a point in the village of Hempstead, which points are less than five miles apart, alleging that it had a right to do this since one of the points was outside the legal jurisdiction of the municipal authority granting the franchise. The Public Service Commission holds that the Commissioners of Highways had the power to limit the fares to be charged by the company both within and without their jurisdiction, as a condition to granting the franchise; also that any ambiguity in expressing this limitation "must operate against the grantee and in favor of the public."

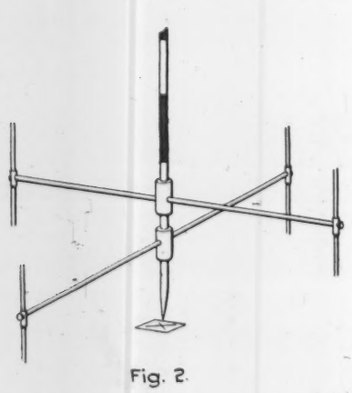
Fig. 2.

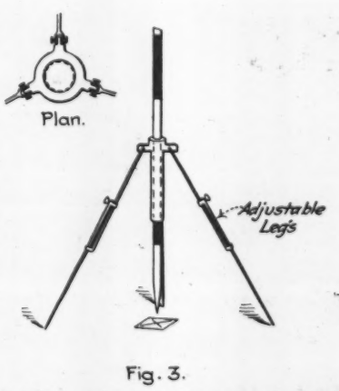

Fig. 3.

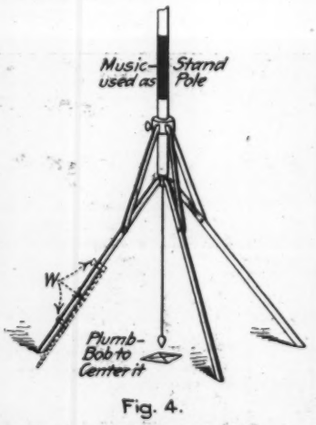

Fig. 4.

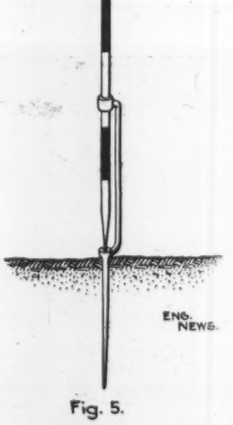

Fig. 5.

FIGS. 2 TO 5. VARIOUS DEVICES FOR HOLDING A SURVEYOR'S ROD.

A SMALL MAGAZINE OF THE AMERICAN POWder Co., at South Acton, Mass., was struck by lightning on March 15 and exploded. The concussion caused the explosion of a second small magazine nearby. The property loss was very small.

AN EXPLOSION OF GAS wrecked a 5-story building in the business district of Natchez, Miss., in the afternoon of March 14. The explosion blew out the entire rear wall of the building and wrecked an adjoining tenement house. The wreckage took fire and a brisk wind carried the sparks so that 18 residences were fired. It is reported that eight persons were killed and that the town was placed under martial law. The cause of the explosion is attributed to an accumulation of illuminating gas from defective pipes in a system just being installed.

A TRAIN WAS DERAILED on a 40-ft. trestle of the St. Louis & San Francisco R. R., about eight miles west of Bristow, Okla. The locomotive, baggage and mail cars and one passenger car were thrown to the creek bed below, killing two persons and seriously injuring seven or eight. It is reported that the derailment was caused by a large iron nut placed on the rails. This act is attributed to mischievous boys or to negroes seeking revenge for the "Jim Crow" law which recently went into effect in Oklahoma, providing separate conveyances for white and colored passengers.

THE AIRSHIP "RED WING," AN AEROPLANE TYPE, built by the Aerial Experiment Association, of which Dr. Alexander Graham Bell is chairman according to current reports, made a successful flight of 319 ft. over the ice on Lake Keuka, near Hammondsport, N. Y., March 12. It is stated that the machine held a satisfactory equilibrium at 30 mi. per hr. and that the flight could have been indefinitely prolonged except for the buckling of one of the supports of a vertical rear rudder. The machine is stated to be similar to the machine on which Henry Farman made his recent successful flight of one kilometer (see Engineering News, Jan. 16, 1908, p. 68) and carries a propeller driven by a 145-lb., 40-HP. gasoline engine. This propeller is reported to be 6 ft. 2 in. in diameter and to consist of two steel blades. The machine alone weighs 185 lbs. and the propelling apparatus 200 lbs. The total supporting surface is 453 sq. ft. A horizontal steering plane is carried in front, similar to those on the other successful machines. By many persons Dr. Bell's active interest in the "Red Wing" is taken to indicate that he has given up work with his multi-cellular tetrahedral type (see Engineering News, Jan. 16, 1908) although no authentic statement of this has been published. His tetrahedral kite, which was launched from his laboratory in November, 1907 (see Engineering News, Nov. 28), it now is reported, was given a final trial on Dec. 6, during which a load of 950 lbs. was lifted, including one aeronaut. In landing the kite was wrecked.

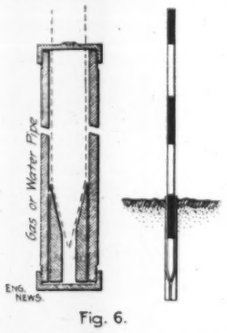

Fig. 6.

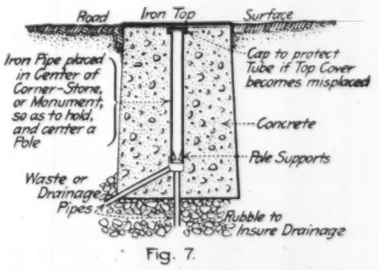
Road
Iron Top
Surface
Iron Pipe placed in Center of Corner-Stone, or Monument, so as to hold, and center a Pole
Cap to protect Tube if Top Cover becomes misplaced
Concrete
Pole Supports
Waste or Drainage Pipes
Rubble to Insure Drainage

Fig. 7.

FIGS. 6 AND 7. BOUNDARY MONUMENTS ADAPTED FOR HOLDING RODS.

THE "MAURETANIA" AND "LUSITANIA," the big Cunard liners, are once more breaking the records for transatlantic steamship speed. On account of the long route which the steamers take at this time of the year the total distance covered is longer than that over which the records of last fall were made. On the trip ending March 12, from New York to Liverpool, the "Mauretania" made the passage of 2,932 miles in 5 days and 5 minutes, averaging a speed of 24.42 knots per hour and breaking all eastward transatlantic records. On March 10 the "Lusitania," westbound, made a 24-hour run of 627 knots, averaging 25.17 knots per hour, the highest 24-hour run of either of the two ships.

EXPORTS OF IRON AND STEEL PRODUCTS from Eastern seaboard points in the month of February broke all records for any single month. The total exports of steel rails, billets, beams, blooms, bars, plates, hoops, wire, pipe, etc., was 92,036 tons, which compares with 33,000 tons exported in February.

THE WATER SUPPLY AND TYPHOID SITUATION of Chicago and vicinity is discussed in the weekly bulletin of the Chicago Department of Health (Dr. W. A. Evans, Commissioner) for March 7, 1908. During the week ending on the date named, there were 15 deaths from typhoid in Chicago, which is above the normal. The number reported during January and February was 233, which, the bulletin states, "is too high for the winter months in a city where the water supply is as good as it usually is in Chicago." During the week the water of the Chicago River flowed into the lake "much of the time," and as a consequence analyses showed the water supply to be suspicious. The advice is given that the water be boiled while snow and ice are melting. As a result of the conference of representatives of several municipalities held at Indiana Harbor, the following resolutions bearing upon sewage, water supply, typhoid fever, etc., were adopted:

(1) That the sewage from the district south of 87th St. must not be allowed to go into Lake Michigan.
(2) That the people of Whiting, Indiana Harbor, East Chicago and Hammond must (a) boil their water, (b) go further into the lake with their intakes, (c) keep their sewage out of the lake.
(3) That the people of Michigan City must (a) boil their water, (b) stop pumping Trail Creek sewage through their water pipes when ice gets in the lake intake, (c) build a stand-pipe or use blow-pipe to clear ice from intake, (d) go further into the lake with their intakes, (e) keep their sewage out of Lake Michigan.
(4) That the people of Gary must (a) boil the water from their wells, (b) heat their milk, (c) cook their vegetables and fruit, (d) eat nothing raw, (e) screen against flies, (f) either use the dry earth system for their yard privies or (g) build cement vaults.
(5) That no yard privies should be allowed where the density of population is greater than 10 to the acre.
(6) That where there are yard privies they should be of either the dry earth type or else of cement, waterproof construction.

GRAPHITE AS A LUBRICANT for ball-bearings has been experimentally studied by Professor W. F. M. Goss, now Dean of the Engineering School of the University of Illinois. The results of many tests in a lubrication testing machine have shown that:

(1) A combination of graphite and lard oil makes up a lubricating mixture which, when applied to ball bearings, will accomplish everything which lard oil alone will do and which at the same time will give a lower frictional resistance of the bearing and permit a large increase in the load which it may be made to carry.
(2) An oil as light as kerosene, when intermixed with graphite, will be converted into an effective lubricant for ball bearings when operated under light or medium heavy pressure.
(3) Even so viscous a lubricant as vaseline will better perform a given service in the lubrication of ball bearings when supplemented by small amounts of graphite. The bearing to which the mixture is applied will work with less frictional resistance and will carry a heavier load than when vaseline alone is used.
(4) The admixture of graphite with either a liquid or a viscous lubricant serves both to reduce the friction and to increase the possible load which a bearing thus lubricated can be made to carry.

The mixtures used for these tests were in each case 4%, by weight, of flake graphite and 96% of the particular carrier studied. As some previous experimentors have not found such favorable results it is fair to state that Dean Goss used only the highest grade of flake graphite made by the Dixon Crucible Co., of Jersey City, N. J.

SMALL AUTO-TRANSFORMERS for use with low-voltage, metallic-filament lamps have appeared in British markets. The present designs are such as to require changes only to the fixture carrying the lamps. These transformers are cylindrical, 3⅞ ins. in diameter by 6 ins. high and weigh about 6 lbs. Evidently one transformer is to be attached to each fixture in a room.

AN ENCLOSED FLAMING-ARC LAMP, known as the "Jandus type," has been placed on the market in England. The action of the lamp is described in the two London journals, "Electrical Engineer," Feb. 27, and "Electrician," Feb. 28. The lamp was designed with two objects; to produce light from gases at a temperature of incandescence without combustion of chemicals and to cause the circulation of gases past the arc. The lower electrode, the positive, is held in a fixed support with the movable electrode directly above it. Surrounding the arc is a clear glass cylinder and outside of this is a translucent globe closely fitting about the top and bottom of the cylinder, but not communicating with the interior of the latter. The inner glass cylinder is in communication with the metal side tubes, so that there is a circulation of the gases evolved up the cylinder and down the side tubes to the bottom of the cylinder. It is stated that any particular body of gas circulates past the arc several times before finally condensing and settling in the outer tubes. The inner glass cylinder is kept free from deposit for the greater part of its length as a result of the high temperature and strong draft. The negative electrode, operated by a familiar mechanism, is an ordinary high-grade carbon, and while the positive is also of high-grade carbon, its cross-section shows a star-shape with the interbrachial spaces filled with a chemical composition, the nature of which is not disclosed. The lamp is cleaned by removing a conical plug, at the lower junction of the two tubes and the cylinder, and with this plug also the inner cylinder and lower electrode, which are carried by it. The life of a pair of electrodes is about 70 hours. It is stated that no shadows are thrown by the side tubes with a good diffusing outer globe. The mean hemispherical candlepower is claimed to be 2,200, and the lamp seems adapted for direct-current circuits only.

A SPIRAL RIVETED PIPE LINE some 30 miles in length has been built for the Goldfield Consolidated Water Company, Goldfield, Nev., according to the "Engineering and Mining Journal" of Feb. 8, 1908. The pipe is 7 ins. in diameter, is dipped in asphalt, and is composed of plates of Nos. 14- to 18-in. gage. The line is designed for a factor of safety of 6. In the line there is an inverted siphon 18 miles in length, with a maximum pressure of 250 lbs. per sq. in. The joints in the pipe are described as having been "united by means of special cast-iron collars drawn together by bolts over a ring of cast-iron which tapers in both directions from the center." A rubber gasket is placed in the collar and ring. The pipe line conveys water from springs at Lida with a combined daily flow of 800,000 gals. Although the springs are said to be from 1,000 to 2,000 ft. above Goldfield, it is stated that it was "impracticable to grade the pipe line to deliver" water by gravity. Consequently a 400,000-gal. Gould's vertical triplex pump, belt-driven by a 30-HP. Westinghouse motor, was installed. This pressure works against a pressure of about 150 lbs. per sq. in. The pump will be duplicated later on. The article states that the maximum price charged for water delivered through the street mains will be ¾-ct. per gal. Until distributing mains are provided for the outlying sections of Goldfield, these sections will be supplied with water from tank wagons.

A HIGH PRESSURE FIRE-PROTECTION WATER supply system for Oakland, Cal., is to be introduced by the city to supplement the regular supply furnished by the People's Water Co. Salt water will be pumped, in emergencies, from Lake Merritt, an arm of Oakland Harbor, in which water is held at mean high tide level by means of automatic gates. The pumping plant will be housed in a reinforced concrete building, designed with a view to the fact that it will be located in a park. Two centrifugal pumps of 1,000 gals. per min. capacity each, capable of maintaining a pressure of 200 lbs. at the station, will be installed at once and a third will be added, for reserve, later on. Each pump will be driven by a 250-HP. gas engine, using California No. 1 engine distillate. Mr. F. C. Turner, City Engineer of Oakland, who has kindly furnished us the information here given, states that with the present water supply fire engines are required; also that the engines "which use fresh water" [meaning the fire engines, we presume] will be retained, "the salt water being used only in case of failure of the fresh water supply or need of additional streams or pressure." Mr. Turner states, further, that:

A small electric motor and plunger pump will be installed to pump water into an accumulator. A 10-HP. gas engine and two-stage air compressor will also be provided. This compressor will furnish air for starting the engines, also to the accumulator and for raising sewage from the pumping station to the sewers. By means of automatic control of the motor, the pressure on the distributing system will be held at about 50 lbs. when the main pumps are not operating. This is not for supplying water, but to show on the gages at the station the condition of the mains and hydrants.

The high-pressure mains will cover the business, mill and lumber yards districts. They will probably be placed two blocks apart, and will be cast-iron bell and spigot pipe, of a minimum size of 10 ins. The whole system is to be built out of current revenues, so the mains will be laid in sections, as money is available. Bids for the pumping machinery will be received on March 18, 1908.

VOLUMETRIC EFFICIENCIES OF AN AIR COMpressor were investigated recently by W. Hellemann in the compressor plant of the Royal Technical College at Dresden, Germany. The two compressor cylinders tested were: I., 10.2 ins. diameter by 11.8 ins. stroke, double-acting, with tail-rod and oscillating rotary valves; II., 8.65 ins. diameter, 11.8 ins. stroke, single-acting, poppet-valves. The compressor has three cylinders, but only two were used in the tests; the machine is belt-driven. The delivery pressures were varied from 21 lbs. to 114 lbs. per sq. in. (gage), and the speeds from 52 to 108 r. p. m. The chief quantities obtained from the tests were: (1) The ratio of volume of air measured at suction pressure to piston displacement, called volumetric ratio; (2) the ratio of air volume measured under atmospheric conditions to piston displacement, called capacity ratio; (3) the

ratio of isothermal energy of delivered air to the indicated work of the compressor, called indicated efficiency. For cylinder I, the volumetric ratio varied from 93.4 to 97.2%, the capacity ratio from 73.0 to 91.9%, and the indicated efficiency from 55.1 to 76.8%, when the rotary valves were worked without pressure equalization. Substituted valves with pressure equalization gave materially lower figures, namely volumetric ratios of 92.9 to 95.1%, capacity ratios 57.8 to 84.4%, and indicated efficiencies of 42.4 to 68.5%. The indicated power in both series of tests ranged from 4 to 20 HP. Cylinder II, fitted with poppet valves, gave the following results, with indicated powers of 1.6 to 7.9 HP. Volumetric ratio 90.2 to 94.5%, capacity ratio 83.2 to 94.5%, indicated efficiency 63.4 to 73.1%.

The results show a very variable relation between volumetric ratio and capacity ratio, which latter figure is of most practical interest. An attempt to calculate the latter from the volumetric ratio, full temperature observations being made, gave results differing from the true value by the maximum amounts of 7%, 21% and 34% in the three series of tests. The amount of cooling water used in the cylinder jackets was found to have little influence on the volumetric ratio, but naturally a considerable influence on the capacity ratio, the latter being increased by increased cooling. Both the capacity ratio and the indicated efficiency decrease with increasing ratio of compression and the decreases were considerably larger in cylinder I than in the other. ["Zeitschrift des Vereins Deutscher Ingenieure," Feb. 8, 1908.]

HALF A MILLION ACRES OF LAND will probably be under irrigation in 1908, in connection with the various irrigation projects of the U. S. Reclamation Service. The location and acreages of the land which it is expected will thus be under water are as follows:

State.	Project.	Acres.
Arizona	Salt River	50,000
Idaho	Minidoka	74,000
Idaho	Payette-Boise	55,000
Kansas	Garden City	8,500
Montana	Sun River	16,000
Montana	Huntley	29,000
New Mexico	Carlsbad	20,000
New Mexico	Hondo	10,000
New Mexico	Leasburg	15,000
Nebraska-Wyoming	North Platte	40,000
Nevada	Truckee-Carson	100,000
North Dakota	Williston	5,000
North Dakota	Buford-Trenton	3,500
Oregon	Klamath	20,500
Oregon	Umatilla	7,000
South Dakota	Belle Fourche	12,000
Washington	Sunnyside	44,000
Wyoming	Shoshone	13,000
Total		522,500

A 50-TON DERRICK CAR for bridge renewal work has been built by the Chicago, Milwaukee & St. Paul Ry. The car is 50 ft. long, with trucks 40 ft. c. to c. It is of steel construction throughout, with boiler and engine enclosed by a cab at the rear end. One of the axles of the rear truck can be driven from the engine by a sprocket chain. At the front end of the car is an A-frame, with eyebar connections to anchors which are secured to the plate girder sills. The box-lattice boom is in two sections, and is adjustable in length by the use of sections 15 ft. and 21 ft. long. At the head are eyebars attached to the blocks of the hoisting tackle and topping lift. The car weighs about 95 tons. With a 42-ft. boom, the hoisting capacity is 50 tons, and the reach is 7 ft. (or 15½ ft. with outriggers to extend the width of base support). With a length of 57 ft. the capacity is 35 tons, and the reach 19 ft., or 8½ ft. with or without outriggers. With the maximum length of 80 ft., the capacity is 10 tons, but the reach is 12 or 27 ft. with or without outriggers, respectively. The car has apparatus for supplying compressed air for riveting hammers, and has a supply car, or tender for fuel and water. In transportation the eyebars of the backstays are uncoupled from the A-frame, which is then swung back upon the floor of the car. The machine was designed under the direction of Mr. C. F. Loweth, M. Am. Soc. C. E., Engineer and Superintendent of Bridges and Buildings.

FIRES IN TWO REINFORCED-CONCRETE BUILDings during the past three months have demonstrated the admirable fire-resisting qualities of this class of construction. On Dec. 13, 1907, a fire broke out in the ninth floor of a ten-story reinforced-concrete building at the corner of 18th St. and Irving Place, New York City, occupied by the Huyler candy factory. The building is a very good example of modern reinforced-concrete construction, with metal trimmings, wire glass windows and fire door protections for all openings. Although the fire was very fierce, owing to a large number of packing boxes which were stored on this floor, the blaze was confined to the floor where it started. Before the firemen could completely control the fire it became necessary to break in many of the windows to allow an exit for the smoke.

On Feb. 20, 1908, fire broke out in the fourth story of the reinforced-concrete building of the Dayton Motor Car Co. at Dayton, O. This building is a six-story structure recently built under the Kahn system of reinforcing, immediately adjoining a brick and timber factory belonging to the same company. The floor on which the fire started was what is known as the upholstering department and contained machines in course of completion and a great amount of highly inflammable material, such as excelsior, hair, leather and paper. The blaze completely gutted this floor of its contents and charred the wooden window and door frames, but did not extend to the other floors of the concrete building. It did, however, reach the mill building and completely destroyed its interior. The new buildings had not yet been equipped with sprinklers but those in the adjoining brick structure, which were in good working order, could not save it from destruction.

In both of these fires the flames seriously damaged the surface of the concrete to the depth of about an inch, thus showing the necessity for a sufficient fire proofing coating over and above the amount of concrete necessary for strength and to completely surround the steel. In both cases, however, this surface damage was so small that it could easily be repaired by cement mortar plastering.

THE INTERNATIONAL HIGHWAY CONGRESS referred to in a letter from a Paris correspondent in our issue of March 5, p. 257, is to hold its sessions in Paris Oct. 11 to 18. The State Department has been officially notified of the Congress by Ambassador Jusserand with information that an invitation to the Government to appoint official delegates will follow shortly. The Congress is in charge of a committee of organization whose headquarters are at 244 Boulevard St. Germain, Paris.

PERSONALS.

Mr. Robert J. Harding has been appointed Superintendent and Engineer of the Board of Public Works of Poughkeepsie, N. Y.

Mr. E. F. Weitzel has been appointed General Manager of the Colorado Fuel & Iron Co., of Pueblo, Colo., to succeed Mr. W. P. Thompson, resigned.

Mr. F. T. Myers, who has been Division Engineer of the Mississippi Central R. R., with headquarters at Brookhaven, Miss., has been promoted to Chief Engineer of the same road.

Mr. R. S. Stangland has been appointed to take charge of the construction for the complete lighting, heating and power plant which Muralt & Co. are building for the U. S. Naval Hospital at New Fort Lyon, Colo.

Mr. H. W. De Graff, Assoc. M. Am. Soc. C. E., has resigned from the Atlantic, Gulf & Pacific Co. and will enter into a partnership with Mr. H. A. Van Alstyne, M. Am. Soc. C. E., lately New York State Engineer.

Mr. T. C. Powell, Vice-President of the Queen & Crescent Route is to retire from that position, which he accepted last August, and will return to the Southern Ry. as Fifth Vice-President, with headquarters at St. Louis.

Mr. R. H. Pembroke has been promoted to Chief Engineer of the Coal & Coke Ry. Co., with headquarters at Elkins, W. Va. Mr. J. P. Keeley has been promoted to Mr. Pembroke's former position of Engineer of Maintenance of Way.

Mr. David S. Carll, M. Am. Soc. C. E., who has for the past ten years been Chief Engineer and Superintendent of the Capital Traction Co., at Washington, D. C., has been elected a member of the board of directors and made Second Vice-President and General Manager of the company.

Mr. Maynard A. Tenney, who has been connected with the City Engineer's Office of New Britain, Conn., has gone to Cuba on some special work for the Department of Public Works. Mr. Tenney was engaged in much of the roadwork around Havana during the first American occupation.

Mr. Josiah E. Spurr, M. Am. Inst. Min. Eng., lately in the employ of the United States Geological Survey, and Mr. W. Rowland Cox, M. Am. Inst. Min. Eng., who has been a mine manager in Colorado, have organized an engineering firm, specializing in mining work, with offices at 71 Broadway, New York City, 305 Boston Bldg., Denver, Colo., and in the City of Mexico.

Obituary.

Hugh Bonner, who was appointed, on Feb. 10 of this year, Fire Commissioner of the city of New York, died at his home in that city on March 12, at the age of 69 years.

George C. Converse, general superintendent of all of the plants of the New Jersey Zinc Co., died on March 10 on shipboard en route from Alexandria to Naples, Italy, at the age of 53 years.

John Burry, electrical engineer with the Stock Quotation Telegraph Co. and manufacturer and inventor of the Burry printing telegraph system, died suddenly March 12, at his home on Staten Island, in the 47th year of his age.

William March Walton, one of the pioneer engineers on the location of the Panama Railroad and later an engineer in wharf construction in San Francisco, died in Newark, N. J., on March 15, at the age of 79 years.

John L. Smithmeyer, who, with his partner, Paul L. Pelz, designed the building for the Library of Congress at Washington, D. C., died in that city on March 12, aged 76 years. For many years the firm has had a claim before Congress for a proper remuneration for their services in connection with the Library building, but although the Court of Claims had decided in their favor, the appropriation had never been made.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION.
March 17-19, 1908. Annual convention at Chicago, Ill. Secy., L. C. Fritch, 1562 Monadnock Block, Chicago.

AMERICAN RAILWAY ASSOCIATION.
April 22, 1908. Semi-annual session at New York City. Secy., W. F. Allen, 24 Park Place, New York.

AMERICAN ELECTROCHEMICAL SOCIETY.
May 1-2, 1908. Annual meeting at Albany, N. Y. Secy., Joseph W. Richards, Lehigh University, South Bethlehem, Pa.

AMERICAN WATER-WORKS ASSOCIATION.
May 11-16, 1908. Annual meeting at Washington, D. C. Secy., John M. Diven, 14 George St., Charleston, S. C.

NATIONAL ELECTRICAL LIGHT ASSOCIATION.
May 19-22. Annual convention at Chicago. Secy., W. W. Freeman, 29 West 39th St., New York City.

NATIONAL FIRE PROTECTION ASSOCIATION.
May 26-28. Annual meeting at Chicago. Secy., W. H. Merrill, Jr., 382 Ohio St., Chicago.

AMERICAN FOUNDRYMEN'S ASSOCIATION.
June 9-11. Annual convention at Toronto, Ont. Secy., Richard Moldenke, Watchung, N. J.

MASTER CAR BUILDERS' ASSOCIATION.
June 17-19. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.
June 22-24. Annual convention at Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
June 23-26, 1908. Annual convention at Denver, Colo. Secy., C. W. Hunt, 220 West 57th St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
June 23-26, 1908. Annual convention at Detroit, Mich. Secy., C. W. Rice, 29 West 39th St., New York City.

AMERICAN SOCIETY FOR TESTING MATERIALS.
June 23-27. Annual meeting at Atlantic City, N. J. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
June 29-July 2. Annual convention at Atlantic City, N. J. Secy., Ralph W. Pope, 33 West 39th St., N. Y.

THE CIVIL ENGINEERS' CLUB OF CLEVELAND.—At the 28th annual meeting of the club, held on March 10, 1908, the following officers were elected: President, Mr. Willard B. Beahan; Treasurer, Mr. John H. Fox, and Secretary, Mr. Joseph C. Beardsley, 1200 Schofield Building, Cleveland, Ohio.

SOCIETY OF CHEMICAL INDUSTRY.—A "Symposium on Disposition of Refuse in the City of New York" will be held at the next meeting of the society at the Chemists' Club, No. 108 West 55th St., New York City, Friday, March 20, 1908, at 8.15 p. m. The following 15-minute papers will be presented. "Refuse and Its Disposal," by Mr. H. deB. Parsons; "The Present Methods of Collection and Final Disposition of City Wastes by the New York Department of Street Cleaning," by Mr. Edward D. Very; "Final Disposition of Refuse in American Cities," by Mr. Rudolph Hering; "The Final Disposition of City Refuse by Mixed Refuse Destruction" and "The Final Disposition of Refuse in Great Britain," by Mr. J. T. Fetherston; "The Destruction of Waste in Public Institutions and Private Buildings," by Mr. W. F. Morse, and "The Heenan Refuse Destructor," by Mr. E. H. Foster.

NEW ENGLAND WATER-WORKS ASSOCIATION.—The last monthly meeting of the season was held in Boston on March 11. Dr. George A. Soper presented a paper on "The Typhoid Fever Epidemic at Watertown, N. Y., in 1904," and Mr. E. L. Grimes, formerly Chief Engineer of the Bureau of Water Supply of Troy, N. Y., and now City Engineer of Troy, presented a paper on the "Troy Water-Works Extension." Each paper was illustrated by lantern slides. Owing to lack of time, Mr. Grimes was able to do little except explain his pictures. An abstract of Dr. Soper's paper and of the discussion following it is given elsewhere in this issue.

On recommendation of the Executive Committee, Mr. Alfred E. Martin, President of the Association, appointed a Committee on the Conservation of the Natural Resources of the Country, with power to co-operate with like committees of other organizations. The members of the committee are as follows: M. N. Baker, of the editorial staff of this journal, Chairman; Prof. William T. Sedgwick, Massachusetts Institute of Technology; Mr. Leonard Metcalf, M. Am. Soc. C. E., 14 Beacon St., Boston; Mr. Allen Hazen, M. Am. Soc. C. E., 220 Broadway, New York City; Dr. George A. Soper, M. Am. Soc. C. E., 29 Broadway, New York City.